CRANFIELD UNIVERSITY

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A THEORY OF EMERGENCY SERVICE COMMAND STAFF SENSEMAKING PROCESSES

SCHOOL OF APPLIED SCIENCES

PhD THESIS
Academic Year: 2006 - 10

Supervisor: Dr Ip-Shing Fan
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This thesis is submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy

ABSTRACT

Fire Service commanders work in a very dynamic environment. This research investigated the process they use to make sense and thereby develop understanding of situations during the response to a large-scale emergency.

In previous research that investigated decision-making and situation awareness in real-life environments, the need for commanders to understand an incident is emphasised. This research aimed to generate new insights into the process individuals follow to build and improve situational understanding.

An exploratory project phase was used to focus the research. Data from emergency exercises and interviews resulted in the design for the main study regarding application domain, data sources and methodological issues. For the main study, records of publicly available interviews with senior officers of the New York Fire Department on their experience of the response to the events at the World Trade Center on September, 11 2001 were analysed.

Findings include six variations of the sensemaking process structure, which is characterised by distinct stages. A following investigation into why these stages occur took a theory-building approach and revealed two insights. First, process stages are tied to seven hierarchical but interlinked levels of understanding. Second, three groups of underlying mechanisms trigger process stages: four cognitive factors, eight needs to understand and three situational factors. The mechanisms occur in different combinations across process variations and have varying explanatory power.

This study contributes to knowledge on the process of building and improving situational understanding and its link to understanding. A micro-level view of the sensemaking process is provided, showing the specific understanding that is gained and evolves along its stages. The view of sensemaking is extended from understanding what is going on and what can be done to include understanding performance of action.

A review with experts revealed that findings adequately reflect the thinking of commanders during incident response and might have practical relevance for training and command support.

Keywords:
Incident command, business continuity, cognitive processes, command training, understanding

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Abbreviations

FDNY – Fire Department of New York

F&R Services – Fire & Rescue Services

IC – Incident Command

RQ – Research question

1 Introduction

This chapter aims to convey

- Where the researcher's interest in sensemaking came from and the steps on the journey from interest to final research topic definition (section 1.1 and 1.2),
- What questions this study sought to answer (section 1.3) and the purpose of the research (section 1.4),
- The research design, process and the methods used (section 1.5),
- The contribution to knowledge (section 1.6),
- The response of the NY Fire Department to the events on 9/11 and the difficulties they faced (section 1.7),
- The thesis structure (section 1.8).

1.1 Origin of interest

The purpose of this section is to explain where the researcher's interest in sensemaking originated.

Sensemaking in the context of this study is defined as "*the deliberate effort to understand events*" (Klein et al., 2007a:114). The research focuses on the process to gain understanding.

The idea for this research originated from the personal experience of a situation that might be described as an emergency; namely, being confronted with an armed robbery at work. It was a novel situation and there were multiple short episodes of sensemaking going on in the researcher's mind. The robbers' orders sometimes made sense, most of the time they did not, e.g. how are you supposed to hand over money if the gunmen insist that you keep your hands up at all times? There was a discrepancy between standard emergency procedures and what the researcher was thinking about doing, e.g. pressing the alarm button to trigger surveillance cameras is not a good idea because the camera makes noise and if the robbers hear it they will shoot us.

The traditional mechanistic view of stimulus – response seemed too simplistic to explain what was going on. It does not take the thinking into account that goes on in between stimulus and response. Coming across Weick's (1988; 1995) literature on sensemaking in crisis situations years later, the researcher recognised many of the features of this cognitive process from own experience. This sparked the motivation to find out more about sensemaking and how others make sense during an emergency situation. The question was if this is a topic worth researching in academic terms.

1.2 Topic development and research problem

To find out if this was a topic worth researching and what would be a useful study setting, the researcher started an exploratory project phase. Three parallel activities informed each other: Contacting organisations that could be potential project sponsors and grant access to data, conducting preliminary studies in the form of six emergency exercises and interviews (see chapter 2), and literature review (see chapter 3).

The following paragraphs describe the exploratory phase of topic development. This covers testing and abandoning the domains of organisational crisis management and evacuations (despite literature gaps), before incident response of the Fire Services was chosen as the study setting. The following Table 1-1 provides an overview of the main attempts to gain access to data, the corresponding results, what decisions and strategy changes were made as a consequence.

Organisational crisis management

The initial idea was to study the response of crisis management teams in the context of business continuity. Since crises are rare events it was anticipated that the amount of data that could be collected from one organisation would be small. Thus, the strategy was to win support for the project from several business organisations. The researcher had multiple successful attempts to get business organisations involved, including telecoms organisations and a high street bank (see Table 1-1). Unfortunately, the stage of firm commitment was never reached, mostly for confidentiality reasons. Getting access to companies to conduct interviews turned out to be impossible. The first strategy change was made, i.e. from trying to obtain small amounts of data from many organisations to trying to obtain large amounts of data from one organisation. This opportunity was seen with a crisis training provider, i.e. observing crisis exercises and collect data during and after them. However, specialised crisis management consultancies rejected collaboration. Moreover, insights from several continuity and crisis exercises (see chapter 2) was that either the setting was not demanding enough for participants to experience sensemaking occasions or the purpose of the exercise was not suitable for the research, e.g. familiarise with general emergency requirements. This was followed by strategy change 2, i.e. to abandon the context of organisational crisis management and try in another one.

(Aircraft) evacuations

Having abandoned the business organisation context, the researcher turned to aircraft evacuation exercises (see Table 1-1). These exercises are run occasionally in a purpose built facility at Cranfield University. A literature review revealed that there are no studies on passenger sensemaking during aircraft evacuations. Instead, studies focus on testing the influence of different variables on evacuation time, e.g. cabin configurations (see e.g. Muir et al., 1996; Muir and Cobbett, 1997). Other literature on evacuations does not focus on sensemaking either. Instead they focus on e.g. human behaviour during building evacuation (Fahy, 1995) and high-rise fires (Proulx, 2002) or information needs (Kuligowski, 2008; 2009; Proulx and Koroluk, 2006). Despite the literature gap in the evacuation context, a preliminary study (see chapter 2) was only partially successful.

Organisational crisis management		
Getting access to data	**Result**	**Decisions + strategy (changes)**
Telecoms organisation	No access to sufficient data	Decision: Try to gain access at another organisation.
Mobile phone company	After initial talks a decision was made to refuse access to people/data for confidentiality reasons	
High street bank	Collaboration was agreed but a joint workshop for the wider banking community was cancelled last minute and collaboration ceased	Strategy change 1: don't try to get a little data from many organisations, try one organisation that can provide much data. Decision: Contact crisis training providers.
Specialised crisis management consultancies	Collaboration would have required data collection from the consultancy's clients during and after training sessions → refused for confidentiality reasons	Decision: Abandon business organisation context. Strategy change 2: Keep strategy but try in other than organisational crisis management context.
Crisis and continuity exercises (see chapter 2)	Either the exercise or the collected data were unsatisfactory	
(Aircraft) evacuations		
Getting access to data	**Result**	**Decisions + strategy (changes)**
Aircraft evacuation exercise (see chapter 2)	Insights from data unsatisfactory; very rare event/exercises make it unlikely that sufficient data can be collected	Decision: Abandon evacuation context. Strategy change 3: Keep strategy but look for one organisation that has experience with many crises. Decision: Try Emergency Services.
Emergency Services		
Getting access to data	**Result**	**Decisions + strategy (changes)**
Police	No access to people / data granted	Decision: Try to gain access at another organisation.
Ambulance Service	No access to people / data granted	
UK Fire Services (see chapter 2)	Collaboration with training centres in 3 UK counties + international training institution; insights from data unsatisfactory: many people report on many different events	Strategy change 4: within the same organisation look for one event that is experienced by many people, i.e. many accounts from many people on the same event (e.g. public enquiries on disasters).
9/11 oral histories (NY Times)	Interviews from the NY Times archive with members of the NY Fire Department on their experience of 9/11 deliver insights from analysis	Decision: Data set is chosen.

Table 1-1 - Topic development – Data access, results, and consequences for subsequent steps

The data collected from participants of simulated aircraft evacuation trials did allow only partial reconstruction of their sensemaking process but not a complete view. Thus, the decision was made to abandon the evacuation context. Strategy change 3 took place, i.e. look for an organisation that has experience with or experiences many crises to increase the chance that they can provide plenty of data. Thus, the Emergency Services were contacted.

Emergency Services, the Fire Services and incident response

The researcher approached training centres of the Police and Ambulance Services to gain collaboration and access to data (see Table 1-1). However, both organisations were not interested to participate in the research. Collaboration was finally achieved when approaching training centres of the UK Fire & Rescue Services in 6 UK counties as well as The Fire Service College (an internationally renowned training centre for the Fire Services). Data was collected and analysed but still did not deliver desired results. Strategy change 4 took place, i.e. look for accounts from many people on the same event were sought to increase the likelihood of finding coherent patterns in the data. This was found in interviews with members of the NY Fire Department on their experience of the events at the World Trade Center on 9/11.

This means that the context in which the research now took place was that of professional incident responders. The UK Fire & Rescue Service manual on incident command (2008:10) states that "*incidents are characterised by time pressure to take decisions, fast paced succession of activities and tasks to be completed and complexity expressed as inability to predict outcomes of decisions*" as well as that "*a critical success factor in responding to any incident will be the commander's understanding of the whole context and the complete environment within which command is to be exercised*". This reflects the characteristics of the naturalistic settings in which professional emergency responders work.

The characteristics of the naturalistic setting have been described as follows (Orasanu and Connolly, 1993):

- Ill-structured problems in uncertain, dynamic environments,
- Shifting, ill-defined, competing goals as well as multiple event feedback loops,
- High stake decision making under time pressure,
- Multiple players or organisations involved.

In this demanding environment even experienced fire commanders encounter situations which they need to make sense of. This was found in preliminary studies (chapter 2) and in literature (chapter 3). In this research time pressure is seen as a charcteristic of the environment in which people need to make sense. Moreover, high time pressure is regarded as an indicator that sensemaking takes place if decisions cannot be avoided. For example, an incident commander on scene has usually limited time available to take a decision on a course of action. Thus, efforts to make sense of the situation seem highly likely in order to have a basis for decision making.
Sensemaking is the process to gain understanding of a situation. Therefore, a study of sensemaking in the present context requires adoption of the process view.

The need to study sensemaking processes in the fire service domain can be summarised as follows:

- Sensemaking was identified as a vital task in fire fighting,
- Literature describes only high-level sensemaking tasks in fire service response but provides no detail on the specific process,
- No sensemaking process models exist in the context of emergency response or fire fighting,
- Existing models suggest a specific structure that the sensemaking process follows. However, models are not based on all common elements of the sensemaking process (sensemaking occasions - e.g. uncertainty or ambiguity - as trigger, sensemaking activities, cues as input and understanding as process output),
- Understanding as process outcome has been neglected in sensemaking research.

The research gaps (see chapter 3 for details) can be summarised as follows:

- Limited understanding about the sensemaking process, its structure and variations, as used by individuals in the emergency response domain,
- Limited knowledge about what understanding is gained as consequence of the sensemaking process and how it evolves.

1.3 Research questions

It was originally planned to have only one research question (RQ). This was:

Research question 1: What process do individuals follow to make sense of events during an emergency?

However, the findings regarding RQ1 resulted in the discovery of specific patterns in the structure of the sensemaking process. The process was found to occur in specific stages. Therefore, a second research question was formulated:

Research question 2: Why do stages occur in the sensemaking process?

1.4 Purpose of the research

Processes of decision-making and situation awareness have been studied in detail in the context of real-life environments and emergency related situations. However, less is known about the sensemaking process (see description of gaps in section 1.2 and chapter 3). Current sensemaking process models show high-level activities or do not originate from the emergency response domain.

In order to understand sensemaking during an emergency it is necessary to study it from the perspective of the person in the situation in detail. Thus, the purpose of the research was to go further than existing models and apply a micro-lens to the process, rather than describing high-level activities. This would contribute to a deeper understanding of the process that individuals use to build and improve understanding.

Another purpose of the research was to gain deeper understanding of the output of sensemaking processes, i.e. understanding. A process view requires including outputs but this has been neglected in existing research. Investigating the process output would contribute to knowledge about the specific understanding gained as a consequence of sensemaking and what form it takes.

1.5 Outline of research design, process and methods

The detailed explanation of research design and methods can be found in chapter 4. This section provides a high level summary of the research process as illustrated in Figure 1-1.

Section 1.1 explained where the researcher's interest in sensemaking. An exploratory project phase followed, which included a set of preliminary studies (chapter 2) and the literature review (chapter 3). In this phase the topic and application area was narrowed down. Data collection included six emergency exercises and interviews. The insights from data informed the next steps in the project. This way it was possible to refine methods that are suitable for the main study. 15 requirements for study setting and methods were the result of this phase. An initial research design was developed and RQ1 formulated.

Part 1 of the main study analysed interviews with senior officers of the New York Fire Department on their experience of the response to the events at the World Trade Center on 9/11. RQ 1 required a descriptive answer including elements and structure of the sensemaking process. An abductive research strategy was adopted to reconstruct the sensemaking process from the accounts and perspective of interviewees. Sensemaking episodes from interviews were used to build categories of process elements (triggers, activities, cues and outcome). This was followed by building process diagrams to illustrate how components relate. Iterative comparison of process diagrams resulted in the discovery of six different variations in process structure. The findings indicated a specific structure of the sensemaking process, which occurs in distinct stages. The discovery of the regularity in the process structure triggered RQ2.

At this point it was necessary to extend the literature review and adapt the methodology. With now two research questions, the philosophical perspective adopted for this research was that of constructivist realism, taking the middle ground between positivism and idealism. To answer RQ2 a retroductive research strategy was adopted to identify the underlying mechanisms that influence the sensemaking process structure.

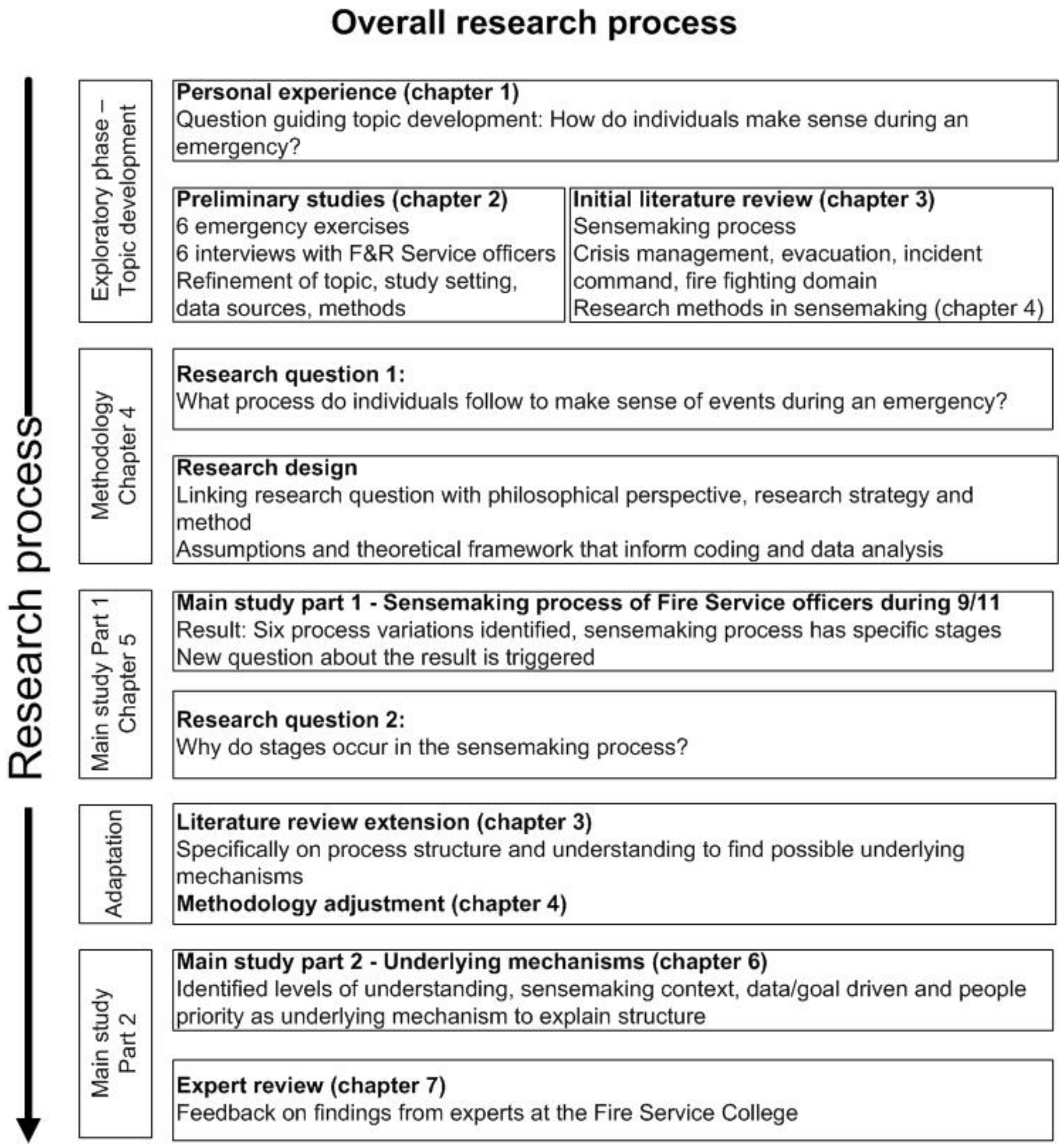


Figure 1-1 - Overall research process

Overall, a constructivist version of the grounded theory approach was used to identify and compare categories in the data.

Part 2 of the main study followed to identify cognitive factors, the needs to understand and situational factors as triggers for stages in the sensemaking process.
The findings were then presented to experts on incident command at the Fire Service College to collect feedback.

1.6 Contribution

The current study contributes to knowledge on the process that people follow to make sense during the response to an emergency situation, i.e. build and improve situational understanding and underlying mechanisms that can trigger process stages. The contribution can be separated into three parts: process structure, understanding as process outcome and their inter-relationship.

The findings of chapter 5 contribute to a better understanding of sensemaking processes in terms of their structure, variations and purpose. Six process variations were found. They offer a detailed view, demonstrating that the purpose of a process stage can be to address limited understanding, taking it to a higher level, addressing multiple gaps or multiple aspects of the same situation. The greater level of detail is useful because it shows that the sensemaking process for a specific situation can be split into several smaller fragments, where sensemaking can be e.g. successful, unsuccessful, about overcoming difficulties to understand something or building on previous insights.

The findings of chapter 6 make a contribution by providing new knowledge on underlying mechanisms that can trigger process stages, on what understanding is gained as a consequence of sensemaking and how it evolves throughout the overall process. This research identified four cognitive factors, eight needs to understand and three situational factors as underlying mechanisms of process stages. Situational understanding takes the form of a seven level hierarchy, which can be summarised as follows:

- Understanding what is going on (levels 0-3)
- Understanding what can be done (level 4-5)
- Understanding performance of doing something (level 6).

Understanding develops across the seven levels in six different ways, showing how it evolves along the process. This extends the current view of sensemaking from understanding “what is going on” and “what can be done” to include “understanding performance of doing something”.

The combination of results in chapter 5 and 6 contributes to better understanding of the link between the sensemaking process, sensemaking context and understanding. The traditional start point (sensemaking context) and traditional end point (understanding) are shown to play an important role during the process in form of changing sensemaking context and interim understanding gained at process stages. Moreover, it was shown that levels of understanding are tied to stages in the sensemaking process.

1.7 Study setting: The NY Fire Department response on September 11

This section provides an introduction to the event that was chosen as data source for the research; namely the response of the NY Fire Department to the events at the World Trade Center on September 11, 2001. It was an exceptional event, where responders faced many novel situations they had to understand and make sense of. Investigating how this is done was the purpose of the research.

The following description is based on a report by McKinsey & Company who were assigned to do an in-depth analysis of the fire operations and response by the FDNY (McKinsey & Company, 2002). The report describes the operational response in detail and highlights difficulties.

Timeline of events

At 08:46am American Airlines Flight 11 crashes into the North Tower of the World Trade Center (WTC1) between the 94th and 98th floor. A fire chief and his crew who witnessed the impact respond immediately. The fire chief transmits a 2nd and 3rd alarm to request dispatch of additional fire units. A 2nd to 5th alarm determines how many units, specialist crews and commanders are requested. A 2nd alarm is a request of 8 engines, 5 ladders and 4 battalion chiefs, whereas a 5th alarm is a request of 20 engines, 11 ladders and 5 battalion chiefs (Anonymous, N.A.; World Trade Center Task Force, 2005). A total of 183 engine and ladder companies, almost all available specialist units (e.g. high-rise, rescue, tactical support, field communications, mobile command, hazardous materials) and 27 chief officers were deployed during the first three hours of the incident (McKinsey & Company, 2002). This equals an estimated 750-850 fire service personnel on site.

A staging area for responding units is designated and the Incident Command Post established in the lobby of WTC 1 by about 08:50 am. Until 09:00 am the Incident Command is handed over three times to the highest ranking officer at the time. Next, it is decided to move the incident command post from the lobby of WTC1 to the outside on West Street. The status of the post in the lobby of WTC1 changes from incident to operations command post.

At 09:03 am United Airlines flight 175 crashes into the South Tower of the World Trade Center (WTC2) between the 78th and 84th floor. Shortly after that a 5th alarm is transmitted for WTC2, where another operations command post is set up in the lobby. The field communications unit is set up near WTC 1 at around 9:15. It is responsible for handling communications, resource tracking, units responding to alarms, tracking assignments and locations. For WTC1 the command focuses on search and rescue because of the high number of distress calls they receive from people in the tower. Units are assigned to respond to distress calls. They move up in the stairwells because elevators are not operational. By now most senior officers of the FDNY are on scene: 26 of 32 staff chiefs responded to scene, 22 before first collapse.

At 09:59 am WTC2 collapses and destroys the incident command post on West Street and the field communications unit. The staff in WTC1 does not know exactly what happened but the collapse caused deteriorating conditions in the lobby of WTC1. The evacuation of the whole tower is ordered. After the first collapse the incident command post is set up further away from the collapse zone. However, many high ranking officers, including the incident commander, return to the scene to assess the damage. They become victims of WTC1 collapse at 10:29 am. The period between the second collapse and approximately 11:28am is one of uncertainty regarding command and control on scene. The chain of command is seriously impaired as it is not clear who survived. Multiple incident command posts are set up at different locations until at 11:28 am a single incident command post is established. Operations continue throughout the following days.

Operational challenges

The McKinsey report (2002) highlights a number of operational difficulties that the NYFD had to cope with. Many of them are reflected in interview passages chosen for this research because they triggered sensemaking processes. The operational challenges were:

- Choice of command post location and decision to relocate,
- Self-deployment of units, i.e. not reporting to the designated staging area, makes tracking and assignment of tasks difficult for commanders,
- Radio communications are not working reliably and prevent the flow of information between units and command,
- Limited and/or unreliable information available to staff at operations command posts inside the towers, they had no information on what is going on outside the towers or the bigger picture of the incident,
- Resource deployment was managed using command boards at the incident and operations command posts. These were destroyed in the collapse, impairing resource tracking capability,
- Crews and commanding staff in WTC1 did not know that WTC2 had completely collapsed. Thus, they were not aware of the real situation development,
- The collapse of WTC2 destroyed the incident command post, damaging the command and control structure,
- The incident commander other key staff became victims of WTC1 collapse. It took an hour to re-establish incident command.

9/11 was an exceptional event. Fire Services had to deal with novel situations that posed challenges to gain understanding of what is going on and what to do about it. Therefore, 9/11 was chosen as study setting.

1.8 Thesis structure

This section provides a brief overview of the thesis organisation by chapter, which is illustrated in Figure 1-2.

Chapter 1	Introduction to the research, providing an overview of topic origin and development, the research context and a summary of methodology and contributions.
Chapter 2	Presentation of insights from preliminary studies. The data and insights informed topic development, application domain and methods.
Chapter 3	Review of literature associated with sensemaking, including its concept, definitions and process elements. Major theories, process models and literature on understanding is reviewed. Research gaps are identified.
Chapter 4	The adopted philosophical perspective and research strategy are presented. Typical methods in sensemaking research are reviewed. The suitability of the chosen research context is demonstrated, the data collection, sample as well as methods and process for data analysis described.
Chapter 5	Findings on sensemaking process structure are presented.
Chapter 6	Findings on underlying mechanisms of sensemaking process structure are presented.
Chapter 7	Feedback from incident command experts on the findings is presented.
Chapter 8	Findings are discussed with regard to existing literature, the wider context of sensemaking and significance. Reflections on the research process, methods, strengths, limitations and research quality are included.
Chapter 9	Conclusion and future research.
Appendices	Appendix A1-A6 refer to chapter 2, Appendix B1-B2 refers to chapter 4, Appendix C1-C4 refers to chapter 5, Appendix D1-D12 refers to chapter 6 and Appendix E1-E2 refers to chapter 7.

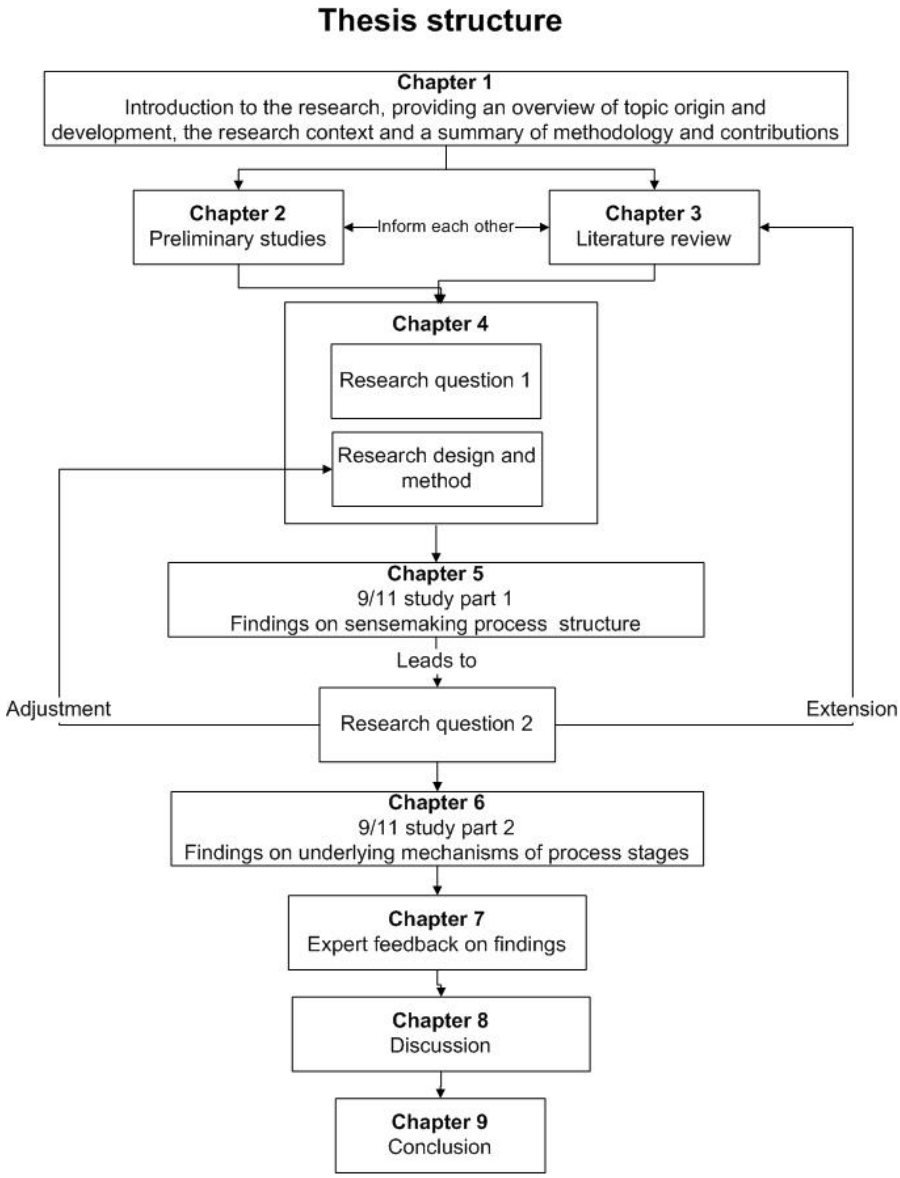


Figure 1-2 – Thesis organisation by chapter

2 Preliminary studies to scope the research

As stated in chapter 1 the initial stage of the research included an exploratory phase of topic development. A suitable research domain had to be identified. The purpose of this chapter is to describe the activities that led to narrowing down the research domain.

The chapter will convey

- Why this exploratory phase was necessary (section 2.1),
- What exercises the researcher attended, what interviews were conducted and what insights were derived (section 2.2.1 - 2.2.7),
- What the 15 criteria are that the main study should fulfil with regard to application domain, study setting and methodological considerations (section 2.3).

2.1 The exploratory project phase

Based on the personal experience of the researcher the broad topic area was defined (see chapter 1). The next step is to narrow down the topic to arrive at a researchable question and phenomenon for which data can be obtained (Richards, 2005). This means to set a boundary to limit the area covered (Blaikie, 2007).

The purpose of the exploratory topic development phase was to identify a suitable domain and methods to study sensemaking. The researcher collected data during six emergency exercises and conducted interviews. An exclusion strategy was followed to eliminate study environment, application area and methods that were judged to be not useful. This phase trained the researcher to refine methods for data collection and analysis and judge suitability of application domains and data sources. Insights from data led the way to plan following steps and formulate requirements for the main phase of the project.

2.2 Overview of six crisis and emergency exercises to scope the research area

This section describes different emergency exercise types. This provides the context for the following presentation of attended exercises. Table 2-1 shows a comparison of attended exercises, which are be described in sections 2.2.1 to 2.2.6.

Crisis exercises are carried out for different purposes, e.g. testing procedures and manuals ('t Hart, 1997) or people skills and performance (Flin and Slaven, 1994; Kleiboer, 1997). Smith (2004) recommends that a simulation should address skills development in terms of coping with unpredictable, complex events and uncertainty.

		Exercise number					
		Exercise 1	Exercise 2	Exercise 3	Exercise 4	Exercise 5	Exercise 6
Exercise characteristics	Exercise type	Table-top exercise	Table-top exercise	Real-time simulation	Real-time simulation	Full-live exercise	Real-time simulation
	Exercise scenario	Premises of a business organisation affected by fire	Response to pandemic outbreak	Aircraft crash in a foreign country	Multiple: Shopping centre, high-rise and residential home fire	Aircraft accident on an airfield	Aircraft evacuation
	Exercise purpose	Familiarise with general emergency response and recovery requirements	Practice response and inter-agency co-ordination (banks and government)	Exercise response of airline crisis managemen t team	Practice incident command skills	Practice response and inter-agency co-ordination (airport, emergency services)	Study time that passengers need to evacuate
	Level of complexity	Low	Medium	High	High	High	Low
	Application area	Business organisation	Financial institutions	Aviation	Fire & Rescue Services	Aviation; Emergency Services	Aviation
	Exercise participants	Members of the local business community	Business continuity professionals	Delegates of an accident investigation short course	Senior officers of UK Fire & Rescue Services	Airport management, Emergency Services	Members of the public as volunteers
	Number of participants	6 groups; 8 members per group	4 groups; 6 members per group	4 groups; 5-8 members per group	13	~ 30	>100
	Participants	Novice	Professionals	Novice	Professionals	Professionals	Novice / experienced
	Roles within the exercise	No specific roles assigned	No specific role within group	Specific roles within the group	Incident, sector, Silver and Gold command	Incident command, executing crews	Passengers and crew members
	Decision- and sense making	Group	Group	Group / Individual	Individual	Individual	Individual
	Time pressure / stress factor	Low	Low	High	High	High	High

Table 2-1 - Characteristics of exercises attended during preliminary study

Training is used to let participants experience what they might be confronted with in a crisis and make decisions under time pressure outside their comfort zone (’t Hart, 1997; Flin and Slaven, 1994; Lee et al., 2007).

Exercise types range from simple review of plans to full-live exercises that involve the whole organisation. Specific competencies are trained (Flin and Slaven, 1994; 1995). Elliot et al. (2002) describe exercise types relevant for this research. Table-top exercises are low stress exercises for the discussion and evaluation of potential responses to an incident (Loewendick, 1993). In simulation exercises a specific scenario is used and includes role plays. Up to 72 hours of the incident are simulated but in a short period of time, e.g. 1 day. Full-live exercises involve a large number of people and organisations and simulate an incident under real conditions, where the level of complexity and time pressure is highest.

2.2.1 Exercise 1

As shown in Table 2-1 exercise 1 was a table-top exercise. It was organised by the Milton Keynes Business Resilience Forum for members of the local business community. The purpose of the exercise was to familiarise participants with possible decisions during an incident that affects their business. Participants had either no or little experience with managing incidents. Thus, the scenario, a fire that spreads slowly and affects business operations for the coming weeks, was of low complexity. It allowed groups of eight participants to discuss and decide actions in a relaxed environment.

Data on sensemaking during the exercise was collected in the week following the event. An online questionnaire (see Appendix A1) was used which 12 participants filled in. It was anticipated that participants new to incident response would encounter plenty of sensemaking occasions as they do not have the experience to deal with such an event. Thus, questions referred to confusing situations, occasions in which they were not sure what to do as well as what helped to make sense. However, answers referred to the lack of clarity in the provided scenario script or questions around roles and responsibilities of involved organisations. These questions were answered mainly in group discussions. Moreover, the researcher observed during the exercise that many questions that would have required sensemaking were avoided by participants by simply referring to a fictional incident response manual that would hold the answer.

Insights on requirements for the present study

First, to study sensemaking an exercise needs to generate sufficient pressure for participants to let them experience sensemaking occasions. Second, participants should not have the chance to avoid dealing with these occasions. Third, the stress free nature of a table-top exercise does not provide this context. Fourth, a useful research environment should exclude exercises where group discussions solve sensemaking dilemmas. Otherwise, the majority of answers regarding sensemaking activities and cues will be “group discussion”, which does not reveal sufficient insights in the sensemaking process of individuals.

The next section describes a table-top exercise as well but with business continuity professionals as participants.

2.2.2 Exercise 2

Table 2-1 shows that exercise 2 was a table-top exercise for business continuity professionals. It took place during a workshop called “Teams in crisis”, organised by the Business Continuity Institute - London Forum. The exercise aimed to practice organisational response to an incident and co-ordinate actions with other agencies. Participants were professionals working in business continuity and crisis management roles for London based business organisations. The scenario, the outbreak of a pandemic, developed in several phases during which groups had to formulate responses and liaise with other agencies. Thus, the complexity level of the exercise was higher than in the previously described scenario but groups worked again in a stress free environment taking collective decisions after discussions.

Although time limits were set to formulate responses, pressure was not high and resulted in limited need to make sense of problems. As in the previous exercise many scenario situations were handled by teams by saying that the detailed response would be available in a crisis plan.

Insights on requirements for the present study

The implication for the main research was that table-top exercises were considered as inappropriate for the study. The main reason was the lack of sensemaking occasions in the scenarios, lack of time pressure and limited requirement to take specific decisions instead of avoiding them. It was concluded that the scenario required sufficient pressure increase the chances of obtaining useful data on sensemaking.

The next section describes a more challenging scenario – a real-time crisis exercise.

2.2.3 Exercise 3

Exercise 3 was a real-time crisis management scenario, simulating an aircraft crash in a foreign country (see Table 2-1). It was organised by the Cranfield University Safety & Accident Investigation Centre for delegates attending a short course on accident investigation. The purpose of the exercise was to let participants experience the situation and decisions that the crisis management team of an airline might be faced with when an airplane crashed. Participants assumed the roles of the airline crisis management team. The simulation was designed to put participants under high pressure by injecting new information about every three minutes for three and a half hours. Every information required decisions that could not be avoided and each group member had a dedicated role and responsibility. Although participants had no experience with managing incidents the level of exercise complexity was high as it covered every aspect of a real crisis – from dealing with operations and media to passengers, casualties, national and foreign agencies – as well as a high level of uncertainty and even false leads.

The researcher participated as observer and message handler during the exercise. Immediately after the exercise data was collected from 9 exercise participants. The tight schedule of the short course and other researchers also distributing questionnaires to the exercise participants did not allow for administering a detailed, lengthy questionnaire or using interviews. Thus, a short questionnaire with two open-ended questions was used (see Appendix A2): 1. What participants had to make sense of, and 2. What helped them to make sense. Four key challenges for sensemaking emerged from the data. These were: creating structure in the response team, information handling, team dynamics and communication within the team as well as with external stakeholders, and, finally, incident characteristics. Insights about what helped people to make sense of these issues could be grouped into three major categories: establish team structure, establish information handling process, visualise information.

The answers refer almost exclusively to organisational challenges of team and information issues. Teams mostly reported challenges on becoming operational as a crisis team. However, organisational issues were not the intended focus of the research. The specific sensemaking process of the individual was of interest. Descriptions of this process could not be obtained.

Insights on requirements for the present study

Implications for this study were three-fold. First, a scenario is required that does not focus on organisational basics of getting the team operational and establishing fundamental processes. This implies, secondly, that exercise participants need to be professionals with advanced capabilities in crisis management who already went through the phase of dealing with basic organisational processes in previous exercises. Third, if a questionnaire is used for data collection, it needs to comprise in-depth questions about sensemaking. Interviews would be more suitable for this purpose and should be the preferred data collection method.

For reasons of obtaining results of no or limited usefulness in Exercises 1-3, crisis management in business organisations was ruled out as application area for the research.

The next section describes a set of Incident Command Simulations with senior members of the UK Fire & Rescue Services at the Fire Service College.

2.2.4 Exercise 4

Exercise 4 was a series of real-time simulations (see Table 2-1), organised by the Fire Service College. The college provides training for the UK and overseas Fire & Rescue Services, business & industry and government agencies. In 2008/9 more than 8000 students attended the 300 offered training courses. 12 courses are offered on incident command.

A group of senior officers of the UK Fire & Rescue Services with an average experience of 23 years on the job practiced their incident command skills. Over the course of several days eight incidents were simulated, each of about two hours duration. Participants were assigned specific roles for each incident: incident commander (on arrival), sector commander, Silver (tactical) and Gold (strategic) commander as well as several command support roles. The incidents included: 1. A fire in a nightclub, 2. A fire in a high-rise building, complicated by a shooting incident; 3. A fire in a residential home; 4. A chemical incident, disguised as fire in multiple locations. The incidents developed in real-time, were designed to put individuals under high pressure and had a high level of complexity because of surprising developments and deliberately built in ambiguity and uncertainty. Although participants were professionals, they had to face novel situations.

The researcher participated in four exercises as observer and in one instance as role player. Each incident was followed by a debriefing session. After this session, a short questionnaire was used to collect data on sensemaking during the exercises (see Appendix A3). Like in Exercise 3 the tight schedule and succession of exercises did not allow for the administration of a detailed questionnaire. Participants were asked to describe the most challenging situation they had faced in the scenario, what questions they asked themselves, how they answered these questions and what specifically helped findings answers.
The amount of data collected was limited. Analysis of the questionnaires was useful to identify sensemaking occasions, which were mainly about overcoming the lack of information at the beginning of the incident, response plan development and assessment. What helped to make sense was additional information collection, information clarification, discussions with others and thinking (ahead). However, participants' answers were very brief, preventing detailed description of activities, cues or the complete process.

Insights on requirements for the present study
The implications for the continuation of this study were five-fold. First, the main study should focus on one or two scenarios that can be studied in depth. Ideally, data should be collected from many participants dealing with the same scenario rather than a variety of scenarios. Second, studying one event would require a large sample size to ensure that data patterns can be detected. Third, the preferred method of data collection should be interviewing to ensure that answers have the sufficient level of detail. Fourth, real-time simulations of an incident seem to induce a sufficiently high level of pressure and complexity to create sensemaking occasions. Fifth, observation is not a useful data collection method because sensemaking is an activity of the mind and cannot be observed from the outside.

The next section describes a full-live exercise about an aircraft crash at an airport that the researcher attended as observer.

2.2.5 Exercise 5

Exercise 5 was a full-live exercise of a simulated crash between two airplanes on the runway of an airport (see Table 2-1). About 30 individuals from Fire & Rescue Services, Police, Ambulance and airport authority participated in the exercise. The purpose was to test the response of the airport F&R Services as well as inter-agency co-ordination for a large scale incident. Participants were all professionals. The level of complexity was high with two crash sites. The level of pressure and stress was high with live fires that had to be extinguished, search & rescue operations and medical attention to the injured.

The researcher participated as observer at one of the crash sites. The operational response was observed but communication between exercise participants could not be recorded. Video footage of the incident response at one of the accident sites was obtained. This material is only helpful in determining major response activities but not with regard to sensemaking.

Insights on requirements for the present study

It was concluded that observation is of limited use to reach objectives of this study. Moreover, it was not possible to obtain interviews with exercise participants, especially the designated incident commander so that this exercise was not useful for data collection. However, the work of the Fire & Rescue Services was identified as potential application area for this study. The advantage over business organisations as setting for this study is the frequency with which Fire Services respond to emergencies. Incidents are rare occasions in business organisations and, consequently, obtaining sufficient data is not only a matter of getting access or confidentiality. Thus, individuals in organisations that respond frequently to emergencies should be focused on.

The next section describes an aircraft evacuation simulation.

2.2.6 Exercise 6

Exercise 6 was a series of simulated aircraft evacuations (see Table 2-1), in which the researcher took part and also collected data from participants.

The simulation took place at Cranfield University. A purpose built aircraft cabin with multiple aisles and exits was used. Volunteers completed four evacuation runs, each time starting from a different position in the cabin. Once participants took their positions it took between 1-2 minutes until flight attendants gave orders to evacuate. Each of the four runs took an estimated maximum of 70-80 seconds to be completed. Volunteers were asked to evacuate as quickly as possible. This resulted in competitive behaviour among passengers to simulate a high-pressure and realistic environment.

An online questionnaire was used to collect data on participants` experience of the evacuation trials (see Appendix A4). In order to be able to relate better to respondents' answers the researcher took part in the trials. 76 volunteers provided answers to questions of

1. What they found the most difficult during the evacuation runs and why
2. If they found anything confusing, if yes, what was it
3. If they were at any point unsure what to do, if yes, what was it

For each of the three questions participants were asked to describe what helped them to make sense. Analysis followed the grounded theory approach of data coding, category development, theme building and constant comparison (see Appendix A5 for coding structure). This way, categories for sensemaking challenges (see Table 2-2) as well as themes for the use of activities and cues were identified (see Table 2-3).

Data analysis with regard to what helped passengers to make sense resulted in the development of 15 categories of sensemaking activities and cues. These were grouped into four main themes (see Table 2-3). Based on this categorisation it can be said that sensemaking takes the form of preparation strategies, coping strategies and includes the use of cues related to behaviour as well as audio / visual cues.

Categories of sensemaking challenges	Sources coded
1. Problems related to finding exit location	30
2. Movement of individuals and groups in the cabin	28
3. Problems related to accessibility of exits	28
4. Planning and execution of exit route	19
5. Using cabin crew instructions	19
6. Competitive passenger behaviour	16
7. Deciding which exit to take	16
8. Aisle condition	12
9. Orientation in the cabin	12
10. Cabin layout related problems	10
11. Wrong expectations lead to problems	10
12. Waiting instead of moving	6
13. Environmental cabin conditions	5
Total number of sources coded	211

Table 2-2 - Sensemaking challenges experienced by participants during an aircraft evacuation simulation: categories and sources coded

Main theme	Categories of sensemaking activities and cues	Sources coded
Main theme: Preparation strategies	Building and using local knowledge	32
	Using mental scenarios	15
	Cues and activities used to prepare evacuation	8
	Use of escape plans	6
Main theme: Coping strategies	Activities to determine exit route	27
	Judgement criteria for exit choice	23
	Cues that fail to work	22
	Trial and error	12
	Following other passengers	11
Main theme: Cues related to behaviour	Observation - experience of passenger behaviour	25
	Expectation and knowledge of people behaviour	11
	Formulation of aims that guide behaviour	8
	Using assumptions to guide behaviour	3
Main theme: Audio / visual cues	Audible cues	19
	Visual cues	12
	Total number of sources coded	234

Table 2-3 - Sensemaking activities and cues used by participants in an aircraft evacuation simulation: Main themes, categories and sources coded

Further analysis of the categories and how they are used to deal with the challenges resulted in the discovery of specific cue types. These cue types deliver insights into the number of cues used in a sensemaking process, sequence in which they are used as well as the purpose for which they are used.

The discovered cue types are:

- single cue (including activities as cues and to create cues);
- back-up cue (an additional cue was prepared in advance to be used in case the original one fails);
- complimentary cue (one additional cue has to be found and is used in combination with the original one);
- alternative cue (original cue is discarded and a new one has to be found and used);
- cue chain (many cues are used in a batch-like sequence, i.e. many complimentary cues make a cue chain).

Insights on sensemaking from exercise 6

Insights refer to the relationship between activities and cues, cue properties and cue failure.

The same cue might have a multiple purpose and be part of several categories. Different cues or combinations can solve the same problem. Some categories might also be a direct input on the property level of another category. This is the case for mental scenarios, which become one of several inputs for the use of escape plans. Relationships can be based on consequences. For example, alternatives that have to be used as a consequence of failed cues. Passengers use many cues from different categories for the same challenge. Although tendencies were found to use specific cues for specific problems, each passenger uses cues in different ways and combinations. However, which cues and in which combination seems to differ from passenger to passenger. Therefore, generalisation in terms of rigid if-then rules, e.g. “challenge X leads to use of cue Y”, is not possible.

Several occasions were found where cues or activities are not useful any more or fail to work. This is referred to here as a break point in the sensemaking process, which seems to originate mainly from changing situational or environmental context. This break point represents the cause or influence on the subsequent use of alternative cue or activity. A break point in the process could indicate the end of one phase of the sensemaking process and the beginning of another. However, the data was not sufficient to investigate this further.

Insights on requirements for the present study

The study allowed for a general description of sensemaking occasions and what activities/cues people use to deal with them. However, it was not possible to recreate and describe individuals` sensemaking process from beginning to end (trigger, activities, cues, and output). Rather, the data provided a snapshot view on single fragments of what seemed to be a more comprehensive process. Participants´ answers were more detailed and comprehensive than in any of the previous exercises. However, answers were still not comprehensive enough. Consequently, detailed descriptions of thinking processes are required for the purpose of this research.

With regard to process structure it was learned that it might have different stages as indicated by break points.
What activities and cues are used and in which combination depends on the individual. Thus, the sensemaking process is highly individual and subjective. This means that the topic must be studied from the perspective of the individual, using rich descriptions.

The next section describes interviews that the researcher conducted with senior Fire Service officer.

2.2.7 Interviews with officers of the UK Fire & Rescue Services

The Fire & Rescue Services in the UK are organised by county. The services were approached in five counties and interviews successfully organised in three of them. A total of six interviews were carried out with fire commanders who had experience in incident command and between 12 – 29 years experience on the job. These were five one-to-one interviews and one group interview.

A questionnaire was developed based on two methods: First, Dervin’s (1984; 1992) Micro-Moment Time-Line, a neutral questioning technique to investigate sensemaking. It is based on establishing in detail what happened during a situation, what gaps in understanding existed, how they were experienced and closed. Second, the critical decision method (CDM), a variation of the critical incident method (Flanagan, 1954) used for cognitive task analysis (see Crandall et al., 2006). Here, a timeline of events is established and run through several times with an interviewee to identify critical moments, decisions, strategies and cues. Several authors have adapted this approach for sensemaking interviews (Klein et al., 2007a; see e.g. Sieck et al., 2007; Hutton et al., 2008).

The interview questions (see Appendix A6) aimed to establish a sequence of events for a particularly challenging incident that interviewees had responded to in the past. Based on this, questions ranged from identifying challenging moments that required sensemaking to detecting what questions interviewees had at that moment, what helped them to answer these questions and what cues they used.
A variety of incidents was covered in the interviews, ranging from house fires to road traffic collisions, rescue operations and hazardous material incidents. The data obtained was much more detailed than in any of the previously described exercises. The analysis resulted in an inventory like table, showing

- sensemaking challenges,
- why this situation was challenging,
- questions asked in these situations
- actions and strategies used to make sense, and
- what was found out using these actions and strategies.

This product of analysis is similar to chronological, decision, critical information, knowledge and cue inventories obtained in cognitive task analysis (Crandall et al., 2006). The results were useful to understand some sensemaking challenges, actions, strategies and cues. However, the interviewees’ reports were not detailed enough to allow reconstructing the sensemaking process as a sequence of steps followed.

This means that process components could be identified but not necessarily how they relate to each other.

Several other problems were encountered during the interviews. Some of the reported incidents happened many years ago. Interviewees' memory of these and their own thoughts and actions was at a low level of detail. It might even be that respondents had little self-awareness of their own thoughts and actions. In some instances the researcher felt that the responses given did not reflect what actually happened but were rather textbook responses of how an incident needs to be dealt with. Moreover, the reported episodes were all about successful sensemaking, as if just one action is required to understand a difficult situation. This did not seem to reflect reality.

Insights on requirements for the present study

The results obtained from interviews led the researcher to the conclusion that interviews should be about a fairly recent event to increase chances of obtaining detailed reports. However, if directly asked about sensemaking, participants might not be aware of their own thinking processes. Although able to give a high level account of process components, they might not be able to explain their thinking process as sequence of activities.

Section 2.3 summarises insights and presents requirements for the main study.

2.3 Requirements for the main study

The exercises described above covered a diverse range of exercise types, scenarios, participants and application areas. The exercises ranged from low-pressure, low-complexity table-top exercises to high-pressure, complex live exercises. Scenarios ranged from business interruption and pandemic to aircraft crashes and fire related incidents. Participants had either no experience managing incidents or were professionals. Business settings (general, financial and aviation) as well as incidents that the emergency services would be confronted with were covered. The diversity of exercises was useful to determine their suitability for this research.

The following list of requirements for the main study was derived:

1. High pressure scenario required to generate sensemaking occasions. Alternatively, a real incident might be studied, which should be an exceptional event that people have no previous experience with to ensure that sensemaking occasions take place (Origin: Exercise 1, 2, 4);
2. No opportunity for participants to avoid decision-making or taking actions (Origin: Exercise 1, 2, 4);
3. Limited opportunity to solve sensemaking problem by group discussion preferred (Origin: Exercise 1, 2);
4. Main focus of the exercise should not be on organisational basics (getting organised, getting team operational) (Origin: Exercise 3);
5. Participants preferably professionals to avoid previous point 4. (Origin: Exercise 3);
6. Comprehensive questionnaire for data collection required to ensure enough details about sensemaking are collected (Origin: Exercise 3, 6);

7. Interviews should be the preferred data collection method (Origin: Exercise 3,4,5,6);
8. Access to individuals needs to be ensured (Origin: Exercise 3, 5);
9. Observation is not useful for data collection (Origin: Exercise 4, 5);
10. Focus on one or two scenarios in depth (Origin: Exercise 4);
11. Preferably large sample size to detect patterns (Origin: Exercise 4, 6);
12. If a questionnaire is used then the sample size should be large (Origin: Exercise 4, 6);
13. Rich descriptions of individuals´ experience are required (Origin: Exercise 6);
14. Sensemaking should be studied from the perspective of the individual as they construct sense about the same challenge in different ways (Origin: Exercise 6);
15. Described incidents should be recent events to improve chances of obtaining detailed reports (Origin: Interviews).

Requirements 1-5 refer to characteristics of scenarios and exercise types that would be useful for this research. A real event would be the ideal setting for this study, especially since creating the right level of pressure in an exercise to simulate real conditions is very difficult (Flin and Slaven, 1995; Sniezek et al., 2002). Full-live and real-time simulations would be the next best options. In contrast to organisational crisis management the work of the Fire & Rescue Services fulfils most requirements of application areas and should be explored further.

Requirements 6-15 refer to data collection and analysis. As sensemaking is a cognitive process that cannot be thoroughly studied through observation, this method had to be ruled out. Interviews with details on interviewees´ experience of an event are the preferred data collection method.

2.4 Chapter summary

The chapter presented preliminary studies that were used to narrow down application area and data collection/analysis methods. 15 requirements for the main phase of this study were formulated. As will be seen in the main part of this thesis, the actual event chosen for this research was the response of the Fire Services to an exceptional, real incident and interviews were used for data analysis. For this reason, the following literature review chapter has a focus on sensemaking related to incident command and the work of Fire Services.

3 Review of literature associated with sensemaking

The purpose of this chapter is to review previous work on sensemaking, determine what the current knowledge is in the field, and identify research gaps. Building on the insights from preliminary studies (see chapter 2) the focus is on the sensemaking process, its elements and the fire fighting/incident command domain.

This chapter is split into two parts. Part 1 (section 3.1) aims to convey

- The importance of sensemaking for professional incident responders (section 3.1.1),
- The relevant research domains and definitions (section 3.1.2), the purpose (section 3.1.3), trigger and occasions for sensemaking (section 3.1.4),
- Components of the sensemaking process and how they relate (section 3.1.5),
- What specific research on sensemaking in the fire fighting domain exists (section 3.1.6),
- The difference between sensemaking and situation awareness (section 3.1.7).

As explained in the introductory chapter, emerging findings resulted in a second research question. This required an up-date of the literature review with focus on underlying mechanisms of the sensemaking process. Part 2 of this chapter (section 3.2) aims to convey

- Process components and underlying mechanisms in major sensemaking theories and process models (section 3.2),
- How understanding (as outcome of the sensemaking process) is treated in the literature, how it is defined and what types exist (section 3.2.6),

The last sections of the chapter show

- A comparison of existing theories/models in general, with regard to the process, its elements and outcome (section 3.3),
- How the literature comparison resulted in the identified gaps (section 3.3), and
- The link between research questions and gaps (section 3.4).

3.1 Literature review – part 1

This section looks at the what, when, why and how of sensemaking, i.e.

- why is it important in incident response (section 3.1.1),
- what it is (section 3.1.2),
- what is gained from it (section 3.1.3),
- when and why is it happening (section 3.1.4),
- what is its process (section 3.1.5),
- what is known about it in the context of fire fighting (section 3.1.6),
- how is it different to related concepts (section 3.1.7).

3.1.1 The importance of sensemaking in incident response

The environment in which professional incident responders work was characterised in section 1.7.3. This section will show why sensemaking is an important aspect for emergency responders.

Sensemaking has been identified as crucial task to cope with and reduce uncertainty and ambiguity which characterise the incident response environment. The co-ordination of the response rests on mainly the incident commander's ability to make sense of the incident, its development and the wider context. However, the cognitive processes of incident command, including sensemaking, might not be well understood.

Boin et al. (2005) identify sense-making as one of five critical tasks for crisis leaders (next to decision making, meaning making, terminating and learning). Competencies of effective incident commanders have been described by several authors, e.g. (Flin and Slaven, 1995; Flin, 1996; Flin and Arbuthnot, 2002; Sarna, 2002; Arbuthnot, 2002; Crichton and Flin, 2002) as follows:

- situation assessment
- take decisions with high stakes and under stress
- deal with several problems at the same time
- task prioritisation
- deal with high stress, confusing and uncertain situations
- leadership, communication, delegation, planning
- team working

The importance of sensemaking in the context of fire fighting has been emphasised (Dyrks et al., 2008; Landgren and Nulden, 2007; Landgren, 2006). The incident commander needs to understand the incident and its current status (Jiang et al., 2004). The sensemaking task is mainly with the crew leader or incident commander (Landgren, 2005), whereas the crew depends on orders to execute tasks. Sensemaking is seen as part of decision making activities and might, in the context of crisis management, be described as situation assessment (Helsloot, 2007). Understanding the problem that one is confronted with is a matter of developing this understanding (Orasanu and Connolly, 1993). The reason is that at arrival on scene fire crews have little knowledge and understanding of the incident. It has to be build up, e.g. by conducting a reconnaissance task at first (Dyrks et al., 2008).

> *"A critical success factor in responding to any incident will be the commander's understanding of the whole context and the complete environment within which command is to be exercised."* (HM Government, 2008:10)

How the situation is understood by the commander during the first minutes determines the strategy and tactics of dealing with the incident for the next hours (Klein et al., 2007a). In the context of situation assessment Sarna (2002) stresses the importance of sensemaking, or creating and maintaining the big picture. This is especially challenging as frequent situational changes occur during the duration of the incident (Klein, 1998). In his personal view as practitioner and experienced incident commander for the fire services, function and structure of incident command are well understood, whereas process (which includes cognitive processes of sensemaking) is less well understood. Moreover, incident command exercises can sometimes overemphasise the importance of creating structure at the incident scene at the expense of making sense of what actually happened. In his view flawed cognitive processes contribute to the collapse of sensemaking with fatal outcome for firefighters, see (Weick, 1993; Weick, 1995a; Weick, 2002; Useem et al., 2005).

> *"If cognitive work is indeed critical to effective performance as an incident commander, there is a pressing need to identify discrete behaviors, skills and tools that are essential for success, particularly under conditions of urgency, high stress, grave threats, and uncertainty."* (Sarna, 2002:53)

Problems occur in major incidents when the fire characteristics prevent an accurate situation assessment because a good understanding of the situation to develop goals and measures is hindered. Fredholm (1997) calls this an unlimited situation, where the dynamics of the event are high, the incident might be spread over more than one site and long time periods and multiple resources have to be coordinated. Fredholm (1997) poses the question if commanders have the experience and competence, including cognitive coping processes, to deal with these unlimited situations.

However, it is not only vital to understand the current situation but also to develop an understanding about the likely development of the situation (Fredholm, 1997). This includes anticipating potential problems and preparing ideas on how to respond to them. The goal is to achieve control of the situation.

3.1.2 Sensemaking – concept, research domains and definitions

Different definitions can be found in the literature, depending on the context and origin of studies. The purpose of this section is to show the variations in definition and state the adopted definition for this research.

Weick (1995) is widely cited on the topic of sensemaking. He wrote that

> *"the basic idea of sensemaking is that reality is an ongoing accomplishment that emerges from efforts to create order and make retrospective sense of what occurs. […] Sensemaking emphasizes that people try to make things rationally accountable to themselves and others".* (Weick, 1993:635)
>
> *"Order, interruption, recovery. That is sensemaking in a nutshell."*
> (Weick, 2006:1731)

This means that people, whether as individuals or groups, create their own reality. Our ongoing reality might be disturbed at some point. The process of sensemaking is an effort to return to order by creating meaning and explanations from events (Weick et al., 2005). This explanation applies to everyday situations and specific task related situations of working life. However, it is very generic.

The boundary between sensemaking and other (cognitive) processes is blurred. For Klein et al. (2006a) sensemaking can mean a number of things: creativity in problem solving, curiosity, comprehension of complex events, mental modelling or situation awareness. This view shows the wide application area of the sensemaking phenomenon. The consequence for the researcher is to clearly specify the application domain and what sensemaking means in the specific context studied.

Three major groups might be distinguished as research domains: organisational behaviour, i.e. how individuals and groups make sense of what concerns them as organisation (Weick, 1995; Weick et al., 2005), information use and communication behaviour (Dervin, 1983; Russell et al., 1993), and cognitive processes (Sieck et al., 2007; Klein et al., 2006b).

Weick is often cited as one of the pioneers of sensemaking theory. His study context is that of organisational behaviour. He emphasised that "sensemaking" should be taken literally in that it is the process of "making" something "sensible" so that it can then be interpreted. Sensemaking is related to two basic questions; bringing something into existence and creating meaning about it (Weick et al., 2005). Firstly, we ask what the story is about an unintelligible event and thereby bring it into existence. Secondly, by asking what we should do about it we create some meaning for the event.
This idea is reflected in the seven characteristics of sensemaking, which are shown in brackets of the following description:

> "*Once people begin to act (enactment), they generate tangible outcomes (cues) in some context (social), and this helps them discover (retrospect) what is occurring (ongoing), what needs to be explained (plausibility), and what should be done next (identity enhancement*)" (Weick, 1995:55).

This definition indicates that the sensemaking process is split into two parts, creating and explaining, which involves the use of activities and cues. It also introduces the element of time by referring to the past, present and future. We try to explain now what happened in the past and what we are going to do about it. It is a retrospective discovery process (Weick, 1995; Klein et al., 2006b) but also a forward looking process to anticipate problems and future developments (Klein et al., 2007a; Klein et al., 2006b).

The majority of sensemaking research is concerned with information and communication. Here, Dervin and Naumer (2010) identified four research areas from which sensemaking definitions and models have originated:
Human computer interaction is concerned with finding suitable representations of information to make information search and navigation easier for users. Cognitive systems engineering is aimed at design and embedding suitable systems for cognitive work in the wider work environment. Finally, there are the domains of organisational communication as well as library and information science.
They also identified two extremes from which sensemaking is studied and defined: transmission and communicative approaches. The former emphasises information processing behaviour of humans and measuring what they make sense of and if this is the correct sense. The communicative approach focuses on the user and how understanding, meaning and insight are constructed from information. However, both approaches emphasise the process and its steps to create sense as well as the outcome of the process.

Definitions focus on information representation, information fusion and exploiting information. Large amounts of information need to be organised in either mental or external representations:

> *"the process of searching for a representation and encoding data in that representation to answer task-specific questions."*
> (Russell et al., 1993:1)

In a more high-pressure environment making sense of information has a crucial role. In the context of military operations Ntuen (2008:1), based on his earlier work, defined sensemaking as

> *"a process, a design, or a technique of fusing information in context to derive understanding from fragmentary pieces of information"*.

Making sense of information in emergency and military contexts is vital, as it prepares decision making. This is also reflected in Klein et al's definition of sensemaking as

> *"exploiting information under conditions of uncertainty, complexity and time pressure for awareness, understanding, planning and decision making."* (Klein et al., 2007b:1)

The cognitive process perspective is not immediately obvious from definitions. It originated from the military context, especially the US Army, to understand, enhance and support sensemaking of decision makers for good performance in the battlefield. Acting under adverse conditions it is important that commanders base their decisions on an understanding of the current situation and putting it in the context of what is to be achieved. Thus, it is no surprise then that definitions of sensemaking in this context are based on situational understanding.

Hutton et al. (2008:2) provided the following definition:

> *"Sensemaking is defined as the deliberate effort to understand events and is typically triggered by unexpected changes or surprises that make a decision maker doubt their prior understanding. Sensemaking is the active process of building, refining, questioning and recovering situation awareness."*

This definition emphasises that events might disturb one's current understanding and that it has to be changed or recovered. The specific process of how this is done is subject to investigating the cognitive domain of an individual or group.

Jensen and Brehmer (2005:1) defined sensemaking in the context of command and control as

> *"the process of achieving an understanding of a situation in terms of what to do."*

This definition goes further than the previous one in that there is a specific purpose given for why sensemaking is necessary. Action follows the sense made. One needs to first understand what is going on in order to decide what to do. This means there might be a specific goal that is pursued as demonstrated in Ntuen and Leedom's (2007b) definition:

> *"Sensemaking is the ongoing process of finding out how to act in order to reach one's goal(s)."*

If there are several goals that need to be achieved or the goals change then there are several sensemaking processes that a person needs to go through. The process might also include an understanding of what options are available in a situation as well as consequences as Burnett et al. (2004:3) state:

> *"More generally, a Commander's intent, his understanding of courses of action and their potential effects, are all the products of a sense making activity."*

Here, sensemaking becomes a matter of understanding how elements in the environment interrelate and what the effect is for one's own context, which might be making a decision or working towards a goal.

The definition by Klein et al. (2007a:114) is rooted in research on cognitive processes of individuals in the military and emergency services domain. They define sensemaking

> "*as the deliberate effort to understand events*".

Here it is assumed that a person is focusing on events that he intentionally wants to understand. This effort is characterised by specific cognitive activities that circle around the formation of mental models to understand and explain in retrospect what is going on and mental simulation for anticipation (Klein et al., 2006b). They focus on activities to create, improve, change, question and recover understanding.

This study is concerned with the sensemaking process during the response to an emergency. Thus, the above definition, its origin and related ideas fit well with this context, as the emergency as well as what happens during the emergency needs to be understood.

3.1.3 Purpose of sensemaking

The previous section provided definitions of sensemaking. In this section it is explained what purpose it serves, i.e. what is gained from it.

Four categories can be distinguished for the purpose of sensemaking. First, dealing with situational context; second, figuring out what is currently going on; third, prepare subsequent actions; fourth, anticipating future developments.

Some authors have described the general purpose of sensemaking as dealing with the characteristics of the incident environment. This means to enable us to continually act (Burnett et al., 2005), the reduction of confusion and dealing with uncertainty and ambiguity (Weick, 1993; Ntuen et al., 2006; Ntuen, 2006a). This might be done by creating explanations for what a situation means, especially in dynamic situations where it serves the need to understand what is going on (Klein et al., 2006a). If a situation is to be understood, then sensemaking has the purpose to create, improve, maintain and rebuild situation awareness (Hutton et al., 2008). Whether the sense that was made is correct or not is not important. Instead, emphasis is placed on whether it is plausible for an individual (Weick, 1995; Klein et al., 2006a).
Other authors have argued that sensemaking does not stop at understanding a situation but have emphasised the connection to the ability to act or create knowledge that can be acted upon (Ntuen, 2008; Jensen and Brehmer, 2005). As such sensemaking has the purpose to lay the foundation upon which one can pursue goals (Ntuen and Leedom, 2007b) and prepare planning and decision making (Klein et al., 2007b).
Moreover, the purpose can be directed towards future developments. For instance, to anticipate problems (Klein et al., 2007a), consider consequences of actions (Burnett et al., 2004), establish whether actions serve to achieve goals (Ntuen and Leedom, 2007b) and anticipate trajectories of events (Klein et al., 2006a).

This separation of the sensemaking purpose into four categories shows that they build on each other. One can deal with adverse situation characteristics by explaining what is going on, which is required for planning and decision making, which is the basis for anticipating developments and consequences. This categorisation will help to understand the purpose of what an individual is trying to achieve and might help in the process analysis to separate stages.

3.1.4 Triggers and occasions for sensemaking

The previous section has shown the purpose of sensemaking. Here it is explained when and why it is happening.

When something stops us from understanding or acting, humans experience a gap in reality (Dervin, 1983). These gaps have to be bridged or closed, supposedly through seeking information. Weick et al. (2005) argue that sensemaking happens when our expectations of the state of a situation or the world differs from our perception of it. Unexpected changes of a situation interrupt the current understanding (Hutton et al., 2008). If something, e.g. a surprising event, a set of cues or a breakdown, does not fit our reality, this represents a stimulus for a frame of reference we use to comprehend, explain and understand (Weick, 1995). As a consequence we have to create meaning for this event which enables us to act.
Weick (1995) calls these interruptions occasions for sensemaking. Schön (1983) argued one occasion for sensemaking is to figure out if there is a problem and what it is. The problem is not immediately obvious; one has to use the act of sense-making to convert a tricky event into a problem one can work with. Weick (1995) described situations of ambiguity, turbulence, complexity, information overload as occasions for sensemaking. An ambiguous situation is one in which multiple interpretations of its meaning are possible. In a situation with fast paced developments we encounter unpredictable and unknowable conditions (Weick, 2002). A high rate of situational change in unanticipated or random ways is described as turbulence (Huber and Daft, 1987; Cited in: Weick, 1995). It poses the problem of keeping up with situational development and reduces the ability to anticipate likely developments. Complexity is a characteristic of the relationship of elements in an environment. An increase in complexity, which means an increase in number and variety of elements as well as ways of interaction between them (Huber and Daft, 1987; Cited in: Weick, 1995), confronts a person with the dilemma to derive meaning out of these new elements and properties of the situation. Too much information is just as problematic as too little information.

Milliken (1987) described three types of uncertainty: state, effect and response uncertainty. He defined uncertainty as *"an individual's perceived inability to predict something accurately"* (p.136). If a person has no understanding of how the current state is or might be changing he faces state uncertainty. If the environment changes but it is not clear how this affects one's own situation, then we can speak of effect uncertainty. Response uncertainty is a lack of understanding of what how one should respond to environmental changes and what options are available in the first place.

Also, absence of expected events or situational characteristics can result in surprise and asking why this is not happening (Klein, 1998). There are circumstances under which sensemaking collapses and needs to be regained (Weick, 1993).

The occasions described above trigger a deliberate process to understand and explain what is going on and establish meaning (Sieck et al., 2007; Stein, 2004): The sensemaking process.

3.1.5 The sensemaking process

Section 3.1.3 and 3.1.4 explained purpose, triggers and occasions for sensemaking. This section describes the sensemaking process from beginning to end. This will show important process elements, i.e. sensemaking occasions, activities, input and output, before specific theories and models are reviewed.

According to Weick et al. (2005) the process starts with noticing an event or cues, bracketing, labelling and categorising it. We particularly notice what is novel, unexpected, unusual, negative, extreme or consistent with our goals (Fiske and Taylor, 1991). What people notice and pay attention to depends on their filtering of information in the environment and what they perceive to be relevant or irrelevant, signal or noise. (Starbuck and Milliken, 1988). Categorisation depends on their knowledge of the task environment, experience and expectations to which stimuli are compared. People show individual differences in filtering and placing stimuli into frameworks to make sense. Moreover, they use different frameworks to understand, explain, assigning causes and predict. Thus, sensemaking is a highly individual and subjective process.
Once these stimuli are placed into a framework people engage in activities of comparing past events or situational states with current ones (retrospection), testing assumptions (presumption) as well as testing current and new frameworks and interpretations (action) (Weick et al., 2005). When people act they produce new cues that serve as novel stimuli to be used to advance sensemaking further.

In the context of information and information systems use Dervin (1992; 1983) argued that the sensemaking process is characterised by communication behaviour. Humans seek and use information, and utilize their own as well as others' observations. The activities involved in this process are described as internal, cognitive behaviour, e.g. comparing and categorising, as well as external, e.g. agreeing, ignoring and attending. Russell et al. (1993) characterised the sensemaking process as one with many loops. Loops serve the search to generate a mental or external representation, fit information into the representation and adjust it. The process cycles around information gathering and making sense of it. Building on this model in the context of intelligence analysis Pirolli and Card (2005) presented a more detailed model with two major loops, i.e. foraging and sensemaking. The former includes activities around searching and filtering information, the latter involves development of a mental model that fits the data. They also introduce data driven bottom-up processes, i.e. searching, filtering, representing information and building hypotheses, and goal driven top-down processes, i.e. searching for support, evidence, relations and evaluation of hypotheses.
The Data/Frame theory (Klein et al., 2007a; Sieck et al., 2007; Klein et al., 2006b) focuses on cognitive processes of sensemaking, which are seven activities linked together in loops. The process starts with placing data into a frame to create an initial explanation of what is going on. The frame might be elaborated using new data, questioned when anomalies and inconsistencies are discovered, preserved or compared to other frames. Moreover, people might seek new frames if the current one does not fit or reframe by using new or re-interpreted data. The theory contributes to our understanding of expert cognition in complex environments and explains the activities people use to develop, extend, correct and recover sense.

The duration of the sensemaking process can vary between almost instantaneously to longer periods of time (Landgren, 2005), indicating that it might be a straightforward process in some instances and a longer one in others.

To summarise, sensemaking can be described as a process, which can be split into a stage of creating cues and one of using them with cycles between the two. Thus, the process might be characterised by use of different activity and cue types.

3.1.6 Sensemaking research in fire fighting

Many authors emphasised the importance of sensemaking in fire fighting (Dyrks et al., 2008; Landgren and Nulden, 2007; Landgren, 2006; Landgren, 2005). Jiang et al. (2004) found that the main challenge for the incident commander is to develop and maintain an understanding of the incident and its current status. Sensemaking occasions are around large amounts of information from different sources that have to be integrated, e.g. determining location and nature of the incident (Landgren, 2005), reconnaissance, navigation under low-visibility, handover and briefing (Dyrks et al., 2008), resource locations, assignments, progress and risks on site (Jiang et al., 2004). Moreover, this information might be incomplete or ambiguous (Landgren, 2006).
Sensemaking research in the fire fighting domain has focused on small samples, e.g. (Landgren, 2005; Weick, 1993), only one stage of an incident, e.g. en-route (Landgren, 2005), a specific task in experiments, e.g. orientation (Dyrks et al., 2008; Landgren, 2006), communication behaviour (Landgren, 2005), description of challenges during incident phases (Jiang et al., 2004) or organisational rather than cognitive context (Jeong and Brower, 2008). Jeong and Brower (2008) were the only source for a description of the sensemaking process, which they argue is split into three stages: noticing, interpretation, action.

The main part of the empirical research focuses on developing technology support for information provision and handling to enhance sensemaking.
Dyrks et al. (2008) and Denef et al. (2008) conducted experiments to investigate individual sensemaking during navigation and orientation tasks in an un-familiar environment under low-visibility. This a typical situation that firefighters face when they enter buildings and need to work under smoke conditions. Denef et al. (2008) identified a number of practices that firefighters use to make sense of their space and build a mental picture for orientation. All practices provide reference points, such as walls, doors, windows and corners that are discovered either by observation or feeling one’s way. After such a reconnaissance mission the participants had to communicate their findings to the crew commander. These conversations were studies to identify patterns in sensemaking activities (Dyrks et al., 2008). They found that maps are drawn ad-hoc and serve as visual object to put verbal reports in context and enhance communication. The maps contain reference points for spatial orientation as well as probable risk. The map is a sensemaking objects that others can use for orientation. The commander uses the detailed explanations of his crew to construct a more abstract, bigger picture of the situation. He relies on information to maintain his picture of the situation development.

Toups and Kerne (2007) studied communication and information flows in fire crews. Communication, face-to-face and via radio, is vital to gather and pass on information between crew members and the incident commander.

Based on conversations between incident commander, fire crew and the control centre Landgren (2005) studied sensemaking behaviour en-route to an incident. Being en-route, the main source of information to make sense of incident location and type is the control centre. Low levels of quality and quantity in information as well as ambiguity trigger sensemaking processes, during which activities of seeking clarification, seeking more and different information are used. These activities produce reference points and cues that the crew uses. Thus, their actions will focus these.

Landgren (2006) describes a range of activities and cues that fire crews use to make sense in different stages of an incident. Initially, the crew needs to make sense of the location, type, scale and gravity of the incident. Although information is usually scarce and incomplete at this stage, crew members might form mental pictures of the incident location based on their local knowledge and create expectations of what is happening and how to respond. Assumptions play a large part at this stage. On arrival, the task of the incident commander is to understand the incident type and scale to deploy his resources. Visual cues like smoke and flames, observation of the incident site from various perspectives and frequent reports on the situation are used to understand what is going on and how the incident develops.

The first task of a fire crew on-scene is to find out what exactly is going on to determine the problem they are facing (Dyrks et al., 2008). Hazards, risks, environmental conditions, and safety issues are among the first aspects that need to be made sense of on arrival on scene (Jiang et al., 2004). Quick reconnaissance missions to get an overview of the situation are carried out. During the course of the incident the commander needs to up-date his sense on resource locations, assignments and progress, risks on site from e.g. hazardous material and building conditions.

Weick has studied the conditions under which sensemaking fails (Weick, 1993; Weick, 1995a; Weick, 2002). Inability to change the current sense, notice new cues and up-date one's sense, i.e. create alternative meaning for a given situation can be related to regression. This means that under pressure people might revert to familiar responses that they have trained before although these response might not be applicable to the situation at hand. Other human factors that can potentially influence sensemaking negatively are tunnel vision or task fixation, i.e. noticing less cues in the environment or ignoring cues, which reduces cognitive load but also makes performing complex cognitive tasks harder. A third factor is misunderstanding where people do not listen to carefully to instructions, combine their own observations with those of others or hold back to ask questions when in doubt. Practice, routine, trust in observations and reports of others, and self-respect to combine own views with that of others are suggested as mechanisms against the above described failures. This indicates the importance of having means to recover sense and knowing how to use them (Weick, 1993).

3.1.7 The difference between sensemaking and situation awareness

Sensemaking is not to be confused with situation awareness. Sensemaking is a process to build, maintain and recover understanding as opposed to knowing the detailed and correct state of a situation (Hutton et al., 2008; Jensen and Brehmer, 2005). Especially in the military domain making sense of a situation is equated with being aware of a situation. Endsley (1995:65) described situation awareness as *"an understanding of the state of the environment"* but also as a state of knowledge about the environment (Endsley, 1995a; 2000). Her situation awareness model is characterised by three hierarchical levels of understanding: perception (level 1) of relevant elements in the environment, comprehension (level 2) of their relevance and what they mean in the context of a task, and projection (level 3) of their future state. The model and the associated measurement techniques are specifically suitable for environments in which one knows in advance what cues should be picked up, what meaning should be assigned to them and what inferences should be made about future developments.

However, several authors argue that sensemaking and situation awareness are not the same as they have a different focus. Hutton et al. (2008) argued that situation awareness is the outcome of an assessment to determine the state of a current situation. Developing, changing, and recovering understanding, which is a process and includes sensemaking, is not covered in the model. Jensen and Brehmer (2005) argued that situation awareness is about having a thorough and correct picture of a situation. Thus, it refers to the state of a situation and whereas sensemaking is a process (Burnett et al., 2004). Additionally, the model focuses only on available cues in the environment but neglects the possibility that sensemaking might require the creation of new cues that are not readily available for perception (Klein et al., 2006a).

3.2 Literature review – part 2

This section will give the reader an overview of the main theories and models for sensemaking as well as insights from empirical papers. Particular emphasis will be placed on what is currently known about the sensemaking process, its elements and outcome. Key points on sensemaking context, activities, cues, understanding as process outcome and possible underlying mechanisms for process structure will be presented at the end of each section.

3.2.1 Organisational sensemaking (Weick's approach)

Weick developed a theory of sensemaking focussing on the social processes of how organisations, individuals, groups of people, communities or firms make sense in their environment. Eisenberg (2006) commented that Weick made contributions to enhance understanding of how humans create and organise the reality in which they act and showing that communication, social interaction and language play a vital role in this. Maitlis and Sonesheim (2010) argued that Weick's work made contributions to shape sensemaking research in the domains of crises and change. This is demonstrated in his work on sensemaking in general but specifically in studies in the fire fighting domain where he investigated e.g. the collapse of sensemaking (Weick, 1993; 1995a; 2002; 1996). Moreover, he investigated sensemaking in crises and accidents (Weick, 1988; 1990; 2010) and developed recommendations on becoming a high reliability organisation and organisational safety (Weick and Sutcliffe, 2001). Soffe (2002) criticised Weick's theory, arguing that it is based on a sound theoretical fundament but lacks empirical validation through testing the characteristics in field studies.

Weick distinguishes between the sensemaking process itself, described through 7 characteristics, and organisational sensemaking. The latter is concerned with the influence of organisational working routines, roles, scripts, traditions, controls, incentives, rules, language and symbols on the way people identify themselves and make sense of their lives. These seven characteristics are reflected in his description of sensemaking, which at the same time introduces a sequence for the process:

> *"Once people begin to act (enactment), they generate tangible outcomes (cues) in some context (social), and this helps them discover (retrospect) what is occurring (ongoing), what needs to be explained (plausibility), and what should be done next (identity enhancement)"* (Weick, 1995:55) .

Sensemaking is not the same as interpretation. It brings an outcome into existence (invention) that can be interpreted (new discoveries possible). Thus, sensemaking is a process, not an outcome. It is also different from decision-making as it defines the problem or question that we take a decision about. It precedes decision-making (Weick, 1995).

Once stimuli are placed into a framework people engage in activities of retrospection, presumption and interpretations (Weick et al., 2005). These activities produce new cues that serve as novel stimuli to be used for sensemaking. These activities and their outcome in turn determine what stimuli are further noticed and focused on.

Two characteristics of sensemaking, enactment and cues, are particularly important for this present study because they provide insight into components of sensemaking processes. Weick argued that sensemaking is split into two parts, sensing and making. Enactment means that through our actions we create our reality, conditions, boundaries and feedback in our environment so that we can sense objects and structure to interpret them. Through our actions we create cues which are

> *"simple, familiar structures that are seeds from which people develop a larger sense of what might be occurring"*(Weick, 1995:50)

These cues can be thought of as reference points in a disturbed or unordered reality from which a larger sense is developed. The context of a situation determines what cues are enacted or noticed and generally people notice things that are unusual, novel or stand out. Context is also important to create meaning for a cue, without context a cue cannot be understood. Once it becomes clear what a cue means, then it can be bound to action.

This places particular importance on human action in the sensemaking process. Gioia (2006) wrote that one of Weick's contributions was to show that action precedes understanding and not vice versa. Many definitions provided in section 3.1.2 focus on sensemaking as a precursor to action but neglect that before something can be understood there needs to be human action to create cues and structures to interpret them. This is what Gioia (2006) describes as cognition-action sequence, whereas Weick shows that action precedes cognition.

Weick (2010) showed that cognition and action are tightly coupled. Normally the initial step of sensemaking is to label and categorise cue which helps to simplify an unordered situation and make it easier to comprehend. However, there are also situations where these cognitive tasks make it more complicated to understand, e.g. in the absence, overabundance or case of misleading cues. An untrained non-expert will not know what to look for and what cues could mean. In this case noticed cues do not lead to action. The problem is not to notice unusual things (stimulus driven) but to create meaning about things which is schema-driven.

Key points

- Sensemaking occasions triggers the process, e.g. ambiguity
- Nothing mentioned about changing sensemaking context
- Use of framework for retrospective thinking, presuming, interpreting, which might depend on the individual's background and knowledge
- Activities produce new cues
- Action precedes cognition, i.e. cues have to be created before they can be used
- Cues are bound to context and used to develop larger sense, i.e. indicates evolving of understanding
- Cues can (but do not have to) cause action
- Possible process sequence: action → produces cues → cues are used in activity → leads to understanding → might cause action (cycle starts again)
- Process outcome: resolved sensemaking occasion, e.g. reduced ambiguity

3.2.2 Information/communication approach (Dervin)

Dervin's background is communication behaviour. Her research focus is on developing information and communication systems that take into account how people make sense of information. The significance of Dervin's work is seen in the critique of the traditional communication model and based on this the development of a methodology for studying sensemaking so that communication and information is used in a more effective way (Foreman-Wernet, 2003).

Dervin (1980) criticised the traditional communication transmission model where communication is seen as a mechanistic, linear process. It was assumed that the sender creates information that will have a desired impact as the receiver shares the same view as the sender. Dervin, however, proposed that meaning of messages and information are constructed by receivers from their own perspective and in the specific context of their life, time and place.

A number of assumptions are made about information, communication and user behaviour (Dervin, 1992). These are: continuity of reality, information, perspectives, information as state. People's reality is discontinuous. It may be interrupted at any time in which case people need to construct sense. In these moments humans seek and use information. Information and users cannot be perceived as static, independent entities but need to be treated as dependent to the effect that communication is a dialogue rather than transmission. Thus, sensemaking needs to be studied from the perspective of the actor, not the observer, as most research does.
The perspective shift from information as entity to process of behaviour is reflected in the language Dervin adopted for sensemaking (Naumer et al., 2008). Sensemaking studies have an activity focus. They use verbs rather than nouns to describe how people perceive situations, what information they seek, and what tactics and strategies they use to construct sense.

Dervin (1983:3)(1983:3) defined sensemaking as

> *"behavior, both internal (i.e. cognitive) and external (i.e. procedural) which allows the individual to construct and design his/her movement through time-space. Sense-making behavior, thus, is communicating behaviour"*

and

> *"focuses on how individuals use the observations of others as well as their own observations to construct their pictures of reality and use these pictures to guide behaviour"*
> (1983:6)

Dervin (1983) developed the basic sense-making model as an interrelationship between "Situation – Gap – Use". We need to make sense in a specific situation. The gap constitutes the discontinuity that needs to be bridged and could be described as information gap. "*Gaps have been defined to date as the questions a person constructs as he/she moves through time-space."* (Dervin, 1983:62). Finally, we use our new understanding and put it into action, although this is not necessary the case.

Based on how individuals see their own situation in terms of the above categories they might define questions about their situation (the gaps) (Dervin, 1984). Gaps can be investigated by asking about confusing moments or limited understanding of a situation (Naumer et al., 2008). Bridges might be explored using questions about what helped to improve understanding or ideas, strategies, hypotheses, sources and conclusions a person had (Naumer et al., 2008; Dervin, 1999). Categories for uses describe measures to evaluate consequences, helps, hindrances, and effects of bridging a gap (Dervin, 2001).

Applications of Dervin's approach cover a wide range of domains: Library desks, college classes, information for patients, research communities (Dervin, 1999). The focus in a study depends on the purpose (Dervin, 1992). For instance, studies of information needs looked at what stopped the individual, what questions did he have, what strategies helped, barriers.

Key points

- Meaning constructed by people, taking their perspective is vital
- Process trigger: interrupted reality which causes questions, confusion, limited understanding
- Nothing mentioned about changing sensemaking context
- Cues: termed as "bridges"; are pieces of information, strategies, ideas, hypotheses, sources, conclusions
- Activities: information seeking and use
- Bridges mentioned as means to improve understanding; could indicate that understanding evolves and gaps are only partially closed
- "Uses" might be seen as action that is consequence of understanding, i.e. ability to do something
- Possible process sequence: situation (including trigger) →gap → bridge (seeking and using cues) → use

3.2.3 Data/Frame Theory (Klein et al.)

Klein's work on sensemaking is based on research in the military domain and is influenced by his work on expert decision making in naturalistic settings. The background and interest is in the cognitive activities of sensemaking.

The Data/Frame theory of sensemaking (Sieck et al., 2007) originated from a 3 year US Army research project. The theory includes explanations of the sensemaking process activities on the cognitive level, an interplay between forming mental models and mental simulation (Klein et al., 2006b).

Two definitions of sensemaking are provided:

> It is the "*motivated, continuous effort to understand connections (which can be among people, places, and events) in order to anticipate their trajectories and act effectively*" (Klein et al., 2006a:71).

> "*Sensemaking is a process of framing, or fitting data into a frame, which helps us filter and interpret the data while testing and improving the frame.*" (Sieck et al., 2007:8).

An assumption of the theory is that data is filtered, explained, and interpreted when it is put into the context of other data. These elements are tied together and organised in spatial, causal, temporal or functional dimensions using a frame, which they define as *"a structure for accounting for the data and guiding the search for more data"* (Klein et al., 2007a:118). *"Data are the interpreted signals of events"* (Klein et al., 2007a:120).

People use a framework or viewpoint to start with the process of sensemaking (Klein et al., 2006b). It is a deliberate process to understand and explain what is going on and establish meaning by using or creating a framework (Sieck et al., 2007; Stein, 2004). Maps, stories or scripts are examples for frames. Frames determine how we perceive and interpret data.

Sieck et al. (2007) and Klein et al. (2007a) identified seven sensemaking activities, which are illustrated in Figure 3-1 (adapted from Klein et al. 2007a). The model does not have a distinct starting point as sensemaking can start with any of the activities depending on the situation.

The theory covers how people try to explain a situation, the extension of that explanation, revising the explanation when faced with inconsistent data, fixation on initial explanations, finding weaknesses in initial explanations, comparison of competing explanations, replacing an initial explanation, creating an explanation when no similar one is recognised.

In the first activity, data and frame are connected. Availability and type of data, repertoire of frames and personal features such as stress, workload, goals and commitment influence the selection of frames to fit in the data. This equals coming up with an initial explanation or understanding that might need elaboration.

Elaboration of the currently used frame takes place when collect more data about the environment they are in to extent what they have learned so far.

When inconsistencies or anomalies are recognised, then a frame is questioned. However, as soon as a frame is used, a person has expectations and beliefs which can be violated by inconsistencies. Although inconsistencies are noticed a frame might be preserved by disregarding data that does not fit. The result is fixation on a frame by creating explanations for anomalous data.

They found that comparison of up to three, maybe competing frames can happen simultaneously to identify which is the more suitable one. Reframing is a sensemaking activity to find an alternative way to see a problem or search for different, maybe so far discarded, data. Seeking a frame is not about replacement of one with another existing frame but about the creation of completely new ones. This might be required because existing frames are not adequate to make sense of something.

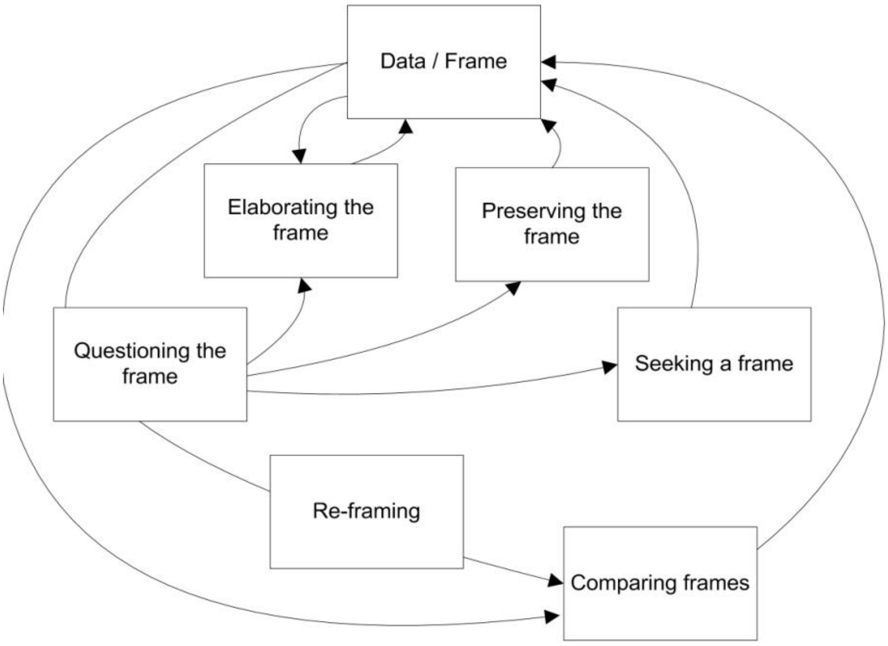


Figure 3-1 - Sensemaking activities in the Data/Frame model

They argued that each of the sensemaking activities has specific strategies and barriers attached. It is necessary to distinguish between the activities in order to provide adequate support for each one. Thus, they see the application of their theory in the development of decision-support systems as well as training programmes.

The research was based on experiments in which individuals were presented with scenarios from incidents during a peacekeeping mission. Previous studies and archival data from domains of fire command, intensive care, army and navy were used to test whether the theory was descriptive enough to cover these contexts. However, no results were reported on this test. Thus, it does not seem to be validated.

This theory rejects the view that sensemaking is an easy, straightforward process. It rejects that people have a preference for easy, linear cause effect explanations. It discards that keeping an open mind without jumping to conclusions or hypotheses early is desirable. Traditional research has found a tendency of confirmation bias. However, a new finding is that people might actually look deliberately for disconfirmation when they question frames. Also, adopting a hypothesis of what is happening at an early stage was traditionally believed to be a strategy that leads to fixation errors. The data/frame theory shows that this is not necessarily the case.

Jensen and Brehmer (2005) criticised the theory. They argued that it is focused on individual but not group sensemaking, that it is similar to models of learning, and that aspect that influence sensemaking cannot be predicted from the model. To date, only one study could be identified that partially applied the data/frame theory by building on its concepts. However, this was in the context of information system and not the emergency domain (see Attfield and Blandford, 2009).

Key points

- Process trigger: not described
- Nothing mentioned about changing sensemaking context
- Frame-breakers, inconsistencies and seeking a completely new frame could indicate that a change of purpose in the process and as trigger for new activities; could also indicate that problems in the process occur that have to be addressed and that a new sensemaking context is triggered here (might be underlying mechanism)
- Activities: putting data into a frame; elaborate, question, preserve, seeking, comparing frames and re-framing; comparison of multiple frames (explanations)
- Cues: Data and frame as reference point
- Data either already exists or has to be created before it can be used in activities
- Process outcome: explanation for an event
- Potential process sequence: any including the above mentioned activities; process elements: use existing cues, create new cues, use cues
- Evolving explanation as one goes through activities, implies improvement

3.2.4 Information representation focus

In the context of tasks involving sensemaking of information, e.g. intelligence analysis, information processing and structuring, several authors investigated specifically the structure of the sensemaking process.

In this context people might deal with large amounts of data. These need to be retrieved, organised and understood. Russell et al. (1993:1) described sensemaking in this context as

> *"the process of searching for a representation and encoding data in that representation to answer task-specific questions."*

Based on a case study of a team reorganising information from printer manuals for a new training, they identified a specific structure in the sensemaking process. This structure is called learning loop complex, which consists of several process steps: searching for a suitable representation of data, encoding data in the representation, identify residue (data that does not fit), shift the representation to include residue, and use encoded representations. It is a cyclic process that starts with an initial representation which is adapted over time to account for new data, correct false or improve current representations. They found this process pattern in four other studies of information rich tasks. This suggests that the sensemaking process might follow a specific process pattern.

Qu and Furnas (2005) built on the work of Russell et al. (1993) and investigated the origin of structure in external representations of information sensemaking tasks. Like Dervin (1983) before, they argue that the development of IT tools to support sensemaking depends on understanding how users come up with structures for external representations of information in the first place. In an experiment with students they found several strategies to construct external representations. Strategies are either driven by own knowledge or driven by the data that is dealt with during the task. The latter included using representations created by others, using ideas that seem only remotely related to the task, and re-evaluation and adjustment of current representations as well as the task itself. They argue that the findings require a revision of the Russell et al. model in that the representation is not only revised in case of residue but along the way.

In the context of intelligence analysis Pirolli and Card (2005) investigated the sensemaking process during information analysis. Based on cognitive task analysis they developed a model of the sensemaking process including data and process flow. The two major parts of the process are a foraging loop to search, collect, filter and narrow down information to relevant bits as well as a sensemaking loop to represent the relevant data and adapt the representation. At each of these stages bottom-up (data driven) as well as top-down (question driven) processes are at work. In the foraging loop the former are search, filter, and extract and the latter search for information, relations. In the sensemaking loop schematize, building a case and present case are the data driven and search for evidence, support and re-evaluate the question driven processes. This extends the model by Russell et al. through adding the foraging loop and more detail to each of the stages. The focus is again on activities in the process but not on the nature of cues and how it relates to the activities.

Takayama and Card (2008) build on the above presented models. They added more activities to foraging and sensemaking loops and introduced planning and helping as new categories.

The four sources show the development of ever more detailed models and activity categories in the sensemaking process during intelligence analysis and information handling tasks. However, they have not looked at the emergency services domain or sensemaking in the context of emergencies. They focus on the information domain.

Key points

- Process trigger: information rich task, large amounts of data
- Nothing mentioned about changing sensemaking context
- Activities: planning, search, filter, extract, represent, encode, use, support, re-evaluate, change representation
- Cues: Data, information, representations
- Data either already exists or has to be created before it can be used in activities
- Process outcome: data representation structure, actionable knowledge, action
- Potential process sequence: search information → represent → encode → use → change representation
- Learning loop complex implies constantly evolving understanding or data representation; current level of understanding might trigger specific activities (might be underlying mechanism)
- Parts of the process might be data-driven, part of it goal-driven; indicates different purposes for different parts of the process (might be underlying mechanism)

3.2.5 Military domain

Burnett et al. (2004) stress the importance of sensemaking for military commanders. Here, sensemaking is used to derive understanding of what to do and the effect of potential courses of action. Klein et al. (2007b:1) emphasise the importance of high quality sensemaking in the military context as

> *"it is expected that individuals and teams will be able to better handle situations despite uncertainty and information overload, make faster and better decisions with regard to the adversary, and finally, prevent fundamental surprise."*

Most of the sensemaking research for the military domain comes out of the US led command and control research programme, aiming to improve practice and understanding of command and control. Their research is published as conference papers.

Jensen (2006) claims that in the military research domain the accepted view of sensemaking is that of a product of situation awareness and understanding. However, in the military domain sensemaking might not focus on the cognitive processes. In the context of command and control it comprises: Understanding what the mission is, understanding the mission context and its preconditions in terms of information and resources available, developing a course of action to achieve the goals of the mission as well as ongoing evaluation of situation development in the light of actions. This description is a mixture of process goals, activities and outcomes but does not show details of each of those.

Jensen and Brehmer (2005) and Jensen (2009) investigated the quality of sensemaking processes during a military planning task. Understanding the mission and situation, identifying, evaluating and deciding a course of action were the tested phases of the process. They found that high quality information does not automatically lead to producing high quality plans and that sensemaking processes with high ratings corresponded to high quality plans.

In the context of military battle Ntuen (2008) stated that the sensemaking process is vital but from a research point of view neither well understood nor formalised. He defined sensemaking as

> *"a process, a design, or a technique of fusing information in context to derive understanding from fragmentary pieces of information [...]. Sensemaking can be viewed as a paradigm, a tool, a process, or a theory of how people reduce uncertainty or ambiguity; socially negotiate meaning during decision making events."* (Ntuen, 2008:1)

Ntuen describes sensemaking as a process consisting of eight stages.

1. Situation is framed to define the problem at hand by formulating expectancies, beliefs and hypotheses;
2. Searching for cues that either confirm or disprove the framed situation;
3. Information is organised into patterns, clusters, taxonomies, diagrams or maps to discover relationships between items;
4. Create meaning of the information by searching for patterns that provide context;

5. Information comprehension;
   However, Ntuen states that situation comprehension equals situation awareness. This point might be criticised because one might be aware of a fact or situation but that does not imply that it is understood at the same time. Moreover, the previous stage of searching for meaning should already have resulted in some understanding.
6. Interpretation of information in terms of what one is trying to achieve;
7. Determine the relevant knowledge for possible action;
8. Derive actionable knowledge to achieve one's goal.

Ntuen does not explain or clearly distinguish the stages in the sensemaking process. He claims that the process originated from earlier experimental and theoretical research but does not provide sources to check this. The stages are described as cognitive process. However, the information mapping stage list semantic diagrams and decision trees. It is doubted that humans create such abstract and ordered constructs in their mind. Moreover, the separation between meaning making, comprehension and interpretation is not clear. In an earlier paper Ntuen (2006a) argued that cognitive processes of reasoning, pattern recognition, analysing if an explanation makes sense and comparing facts might take place simultaneously. However, the above process is sequential. Thus, there is a contradiction between his arguments.
Ntuen and Leedom (2007a) studied sensemaking principles that commanders use in the battlefield. They argued that the sensemaking process is tied to the situation tasks of the battle commander: association of events, recognising vital cues and develop sufficient understanding to act.
Ntuen also published on sensemaking training requirements (Ntuen and Leedom, 2007b) and the use of different knowledge types in the sensemaking process (Ntuen, 2006b). However, these are theoretical propositions without empirical data.

Key points

- Process trigger: Uncertainty, ambiguity, unconnected information fragments
- Nothing mentioned about changing sensemaking context
- Activities: Meaning making, searching for cues, formulating expectancies, beliefs and hypotheses, reasoning, pattern recognition, analysing
- Cues: information, goals
- Data either already exists or has to be created before it can be used in activities
- Process outcome: understanding of available information and resources, suitable course of action to achieve goal, situation development as consequence of course of action; reduced ambiguity and uncertainty
- Potential process sequence: frame situation → search cues → organise information → create meaning → comprehend information → interpret information → determine relevant knowledge required → derive actionable knowledge
- Goal might exist in advance to achieve understanding of a particular situation, mission, course of action (goals might be underlying mechanism)

3.2.6 Understanding as outcome of the sensemaking process

In the context of situational understanding in incident response it is of interest to find out what was understood, what one is able to do rather than the question of what understanding itself is. If sensemaking is an effort to understand, then we need to answer the questions of what the nature of understanding is, whether there are degrees of understanding and what these degrees enable to do. Related literature to these questions is reviewed in the following sections.

3.2.6.1 What is understanding?

Different perspectives exist on what understanding actually is. Descriptions differ between understanding as experience, process, state, act or ability with both arguments in favour as well as against each perspective. Dascal (1981) warned that empirical studies of understanding are problematic because the researcher as observer can recognize understanding only indirectly by interpreting acts, gestures, words or verbal reports, where the latter are already interpretations. Schwandt (1999:452) argued that to

"understand is literally to stand under, grasp, to hear, get, catch, or comprehend the meaning of something".

However, the term "understanding" is used in different ways depending on the context. Sierpinska (1996) argued that the classical philosophical literature, mainly concerned with the literal understanding of words, symbols and conversations, is ambiguous because the terms understanding and meaning are used interchangeably.

The process perspective

Steiger (1998) summarised several theories of understanding as proposed by psychologists. Here, understanding is described as recognizing key relations that form the core structure of a situation or problem. Another perspective is that of understanding a situation by creating a mental model as guidance for actions. Yet another suggestion is that understanding is about creating a representation (model) of what you want to understand. The representation might just be an assumption or hypothesis that needs to be supported or falsified by the use of evaluative or explanatory arguments (Steiger, 1998). The above description has a strong resemblance to the sensemaking activities that were mentioned in the previous sections.

Ziff (1972) argued that understanding is an analytical process. Things that have a structure can be understood if they can be analysed. Sandberg and Targama (2007) describe understanding as a constantly evolving process of refining or changing ones understanding. It develops in a circular manner because to refine and change requires something that is already understood. This again describes a process to manipulate understanding in some way but does not clarify what understanding itself is.

Multiple property perspective

Sierpinska (1996) wrote that understanding might be described

"as a cognitive activity that takes place over longer periods of time—then we sometimes use the term of 'process of understanding' in which 'acts of understanding' mark the significant steps while the acquired 'understandings' constitute props for further development."

This view is similar to Duffin and Simpson (2000) who argued that understanding has three components: building, having and enacting. They suggested that it is an act, state and process at the same time. Building understanding means the continuous process of forming connections in mental structures of already existing understanding. Having understanding is a state, as it is the presence of these connections at any given time. Enacting understanding is the act which puts these internal connections into use.

The ability perspective

Rosenberg (1981) stated that understanding is an achievement, manifesting itself in the ability to do something. Mason (2003) described capacity as a possible model of understanding, expressed as the ability to do something.

Smart et al. (2009) reviewed how the term understanding is used with regard to perception, intentional actions, language and situations. In perception, understanding comprises the ability to sense stimuli and make predictions about their effect. To achieve situational understanding one needs to be able to explain the present and the future. They argue that the elements of comprehension (interpret, combine, prioritise) and projection (form expectations) in Endsley's (1995a) model of situation awareness are relevant for the concept of understanding and suggest that it is dynamic situational understanding.

For Wittgenstein (1963) it is a misconception that understanding is an experience, a mental process, or a state. It is rather like an ability. The ability to do something, e.g. explain, apply, or use correctly, are manifestations of understanding. Baker and Hacker (2005) explain these arguments in more detail. As understanding is intangible it cannot have a form, condition or structural state like an object. One can only have it, have it to a certain degree or not have it. Having understanding is rather the ability to do certain things. Gaining understanding is the transition from not being able to do something to being able to do it. However, it might be more akin to an ability. First, understanding enables to perform various actions and is not restricted to one single ability type. Second, although one might understand something, e.g. a language, one might not possess all the abilities that are associated with it (understanding a language does not mean one is able to speak it). Third, a higher degree of understanding does not necessarily lead to improved performance. Fourth, one might understand an explanation of something but this does not yet enable him to do it, e.g. riding a bike.

It can be summarised that one engages in activities (acts) to build, elaborate and change understanding, where these activities constitute a process. Once understanding is gained it enables us to perform certain things that we were not able to do before. These performances are manifestations and evidence of understanding. There does not seem to be consensus in the literature about what understanding itself is. The next best approach seems to focus not on understanding directly but manifestations of it. And here many authors either openly or inadvertently describe understanding as ability and, respectively, what it enables to do.

Key points

- Understanding is manifested in an ability to do something
- Existing understanding is built upon to create refined or changed understanding, i.e. understanding evolves continuously

- There are different degrees of understanding, which implies a hierarchical structure

3.2.6.2 Levels of understanding and what they enable us to do

The dominant model with regard to understanding situations is the previously described one of situation awareness by Endsley (1995). She described situation awareness as "*an understanding of the state of the environment*" but also as a state of knowledge about the environment (Endsley, 1995a:65; 2000). Both knowledge and understanding are used as terms for being aware what is going on. Understanding is manifested as a series of assessments, such as temporal aspects of the situation, risk, significance, capabilities, severity, and consequences (Endsley and Robertson, 2000). Projection is the highest level of understanding that can be achieved and is required to make decisions that are in line with task objectives or goals and enables anticipation of coming events and their implication (Endsley, 1995a; 2000). However, it must be questioned what is actually understood at this level, as the projection is a mental simulation of potential future developments of a situation and can be nothing more than an educated guess. Moreover, it is possible to have perfect knowledge about the state of a situation and still not understand it.

Two techniques are used to measure situation awareness: Situation Awareness Global Assessment Technique (SAGAT) and the Situation Awareness Rating Technique (SART) (Endsley, 1995; Endsley et al., 1998). Both techniques attempt to measure not how operators understand but what they understand about a situation. Both techniques rely on experts to determine in advance what should be understood in a specific situation.

One might only gain partial understanding of a problem or situation. Thus, understanding might have different degrees. Sierpinska (1996) writes that understanding might be good, poor, full, intuitive or wrong.

One of the goals in the teaching and learning domain is to assess the degree of students' understanding of a subject. Understanding is expressed by specific performances (Perkins and Blythe, 1994). The best known hierarchy is Bloom's taxonomy (Bloom, 1956) of teaching and learning objectives, which has been revised since (Krathwohl, 2002). The cognitive dimension consists of hierarchical categories, where degrees of understanding are manifested in the corresponding abilities (see Table 3-1).

Cognitive dimension categories	**Description of dimension**	**Manifestation of understanding**
Understand	Create and determine meaning	Interpret, exemplify, classify, summarise, infer, compare, explain
Apply	Using or applying rules and procedures	Execute, implement
Analyse	Decompose into parts, discover relationships	Differentiate, organise, attribute
Evaluate	Use criteria to make judgements	Check, critique
Create	Composition of elements in new forms	Generate, plan, produce

Table 3-1 - Five cognitive dimension categories of Bloom's revised taxonomy, their description and manifestation

Smart et al. (2009) argue that understanding is demonstrated by the ability to describe, explain and predict, and that successful understanding might require a knowledge base of relationships between elements relevant for the context we try to understand as well as inferences about unobserved relationships.
Understanding enables to go beyond the limits of current knowledge by making predictions, extrapolating and applying knowledge in new contexts (Perkins, 1993). When one understands a topic then this involves the ability to perform demanding thought processes, such as explaining, generalising, applying, finding representations, analogies and new examples. This includes applying understanding of a concept in new contexts or to different problems as well as evaluating in order to justify claims (Smith and Siegel, 2004).
Rosenberg (1981) raised the question whether something can be fully understood (degree of understanding vs. degree of understandability) and states that if understanding is seen as an achievement then there is not one single classification of what counts as understanding, as this achievement can take many forms. He writes that understanding structure, relationships or limits is what one is concerned with to understand. Ways to understand are analysis (decompose, segment, classify), explanation (reducing ambiguity, interpretation, create new relations and context), elucidation of vagueness (finding boundaries and expressing criteria for what is inside and outside).
Although understanding is dependent on the context, there are some general aspects that apply context independently (Nickerson, 1985). One of these is the degree of understanding. Understanding is not absolute in the sense of right and wrong but has transitions from less to more right or complete. Once a little bit of understanding is gained one can ask further questions. If one understands something deeply then this should manifest itself in several ways, not just a single one.

Key points

- Understanding might be measurable if one can define in advance what should be or must be known in a situation based on available cues
- One might gain only partial understanding
- Possible degrees of understanding: poor, good, full, wrong
- Understanding has its manifestation in specific activities that can be expressed as performance ability
- Activities associated with creating understanding are similar to those found in sensemaking research, e.g. analysing (decompose, segment, classify), explaining (reducing ambiguity, interpretation, create new relations and context)

3.3 Comparison of literature and resulting research gaps

The purpose of this section is to compare and contrast the above presented literature to draw out the research gaps. Table 3-2 and Table 3-3 provide an overview of the comparison and is based on the key points of the previous sections 3.2.1-3.2.5. The following comparison is split into three parts: general, sensemaking process and its elements, and understanding as process outcome.

General

The majority of research seems to originate from the information systems domain. The goal is to investigate how people understand, structure and use of information in order to develop systems that aid their sensemaking. Here, only Ntuen's work is based in a domain related to an emergency environment, i.e. the military. Sensemaking research in the fire fighting domain has also focused on developing technology to support sensemaking or just described sensemaking challenges and tasks. Weick's work focuses on social processes in organisations but is the only author who has looked at this in the context of fire fighting. The theory or models range from very generic to very specific. Dervin's model is very generic which makes it applicable to any research context. It comprises not only theoretical foundation in information and communication theory but also the methodology to carry out research. Klein et al's. data/frame theory is based on empirical data and focused on sensemaking activities and the cognitive processes involved, whereas Weick's theory is not empirically grounded but based on a large body of research on organisational behaviour and cognitive processes. The detail of models with specific process steps ranges from 4 general steps, to an 8 stage process and the most detailed process model is presented by Pirolli and Card. The more detailed the models the more they are focused on a specific application domain.
The sensemaking context as perceived by the individual becomes a vital component of the sensemaking process and should be part of an investigation. If the process is triggered by an event that is perceived by the individual as a sensemaking occasion, e.g. ambiguity, and seen a transition from a situation that does not make sense to a situation that does, then in this example ambiguity should be resolved or at least reduced.

Thus, the sensemaking occasion (in the following referred to as sensemaking context) should make a transition along the sensemaking process. However, in the current literature sensemaking occasions are only described as trigger for the process. No research could be identified that traces its changes throughout the process. However, this is useful to investigate because changes in sensemaking context could indicate a change of purpose or focus, pointing towards a new phase in the process, possibly why these stages occur and why specific activities are engaged in. This relates back to the break points identified in the aircraft evacuation exercises (see chapter 2). Thus, we currently have limited understanding of how sensemaking context develops during the sensemaking process. This constitutes a gap in literature (gap 1).

		Weick	**Klein**	**Dervin**
General	**Background / Origin**	Organisational behaviour	Military domain; influenced by situation awareness and decision making research	Information systems design; how users use information
	Model / Theory	7 characteristics of sensemaking: Identity construction, retrospective, enactment, social, ongoing, extracted cues, plausibility	Data / Frame Theory	Situation – Gap – Use Model
	Source	Journal papers and book	Commercial research report, book chapter, essays, conference paper	Journal papers and books
	Sensemaking focus	Social processes in situational context	Cognitive processes, sensemaking activities	Information and communication behaviour, cognitive and procedural dimension
	Validated	Theory, not empirically developed but based on existing research	Descriptive fit in other domains tested but no results reported	Yes, validated methodology
	Naturalistic, emergency setting	Crises, accidents, fire fighting, especially where firefighters died	Not in empirical study, only descriptive fit in emergency domain	No
	Study focus	How members of organisations organise their reality, social interaction, influence of the organisation on sensemaking	Cognitive processes described as 7 activities	information seeking and use, gaps, uses, situations
Sensemaking process and its elements	**Sensemaking occasions / context**	wide range of occasions cited, especially uncertainty and ambiguity but only as trigger of sensemaking	No triggers described	Gap in form of questions people ask. 8 categories of "situations" might be interpreted as sensemaking context
	Sensemaking process	Not at the heart of the study; the process just explains how people make sense cognitively; characteristics introduce sequence of action-cognition; Focus on 7 characteristics which are not shown as process	Cycle of fitting data in a frame, elaborating, questioning, persevering, comparing, re-framing, seeking new frames; No particular sequence, cycle can start with any activity depending on situation context	No formal process described; Looking at activities and information in terms of situation-gap-use model; find out situation, what the gap is and how it is bridged
	Process input	sensible structures, i.e. cues, but mediated by routines, language, roles, traditions	Data and frame	Information
	Use of cues	Cues as reference points and enactment to extract cues	Critical cues for initial frame; data as cues; connection between cues; cues used for ongoing development of frames	Use of information as cues
	Sensemaking activities	processing, labelling, bracketing, create cues, explain, interpret	Cycle of fitting data in a frame, elaborating, questioning, persevering, comparing, re-framing, seeking new frames	comparing, categorising, agreeing, ignoring, attending
Understanding as process	**Sensemaking process outcome**	Sensible structures and meaning	understanding of connections for anticipation of development and effective action	Understanding and ability to act
	Linking sensemaking to action	action precedes understanding but understanding enables action; not always action	Cognitive activities drive understanding, understanding enables effective action	The outcome of sensemaking is the ability to act; linking specific information to action

Table 3-2 - Comparison of sensemaking literature

		Russell et al.	Pirolli and Card	Ntuen
General	**Background / Origin**	Information processing, Information systems design	Information processing, intelligence analysis	Human Computer Interaction, Information visualisation
	Model / Theory	Learning loop complex	Data and process flow model	8 stage process of sensemaking
	Source	Conference paper	Conference paper	Conference papers
	Sensemaking focus		Making sense of information in intelligence analysis, process structure	Sensemaking as cognitive process, process stages
	Validated	Found in other information rich tasks,	No, initial report on ongoing research	unknown
	Naturalistic, emergency setting	No	No	Yes
	Study focus	Process structure	Process structure followed to make sense of information	
Sensemaking process and its elements	**Sensemaking occasions / context**	Information rich task,	Not described	Uncertainty, ambiguity, unconnected information fragments
	Sensemaking process	4 step process pattern identified: search, represent, encode, shift and multiple learning loops	Process model comprising 2 major loops (foraging and sensemaking loop): collect information, information representation and analysis, use or change representation to create insight	8 stage process: Situation framing, cue search, information organisation, meaning creation, information comprehension, interpretation in terms of goals, determine knowledge for action, derive actionable knowledge to achieve goal
	Process input	Data, data representations, residue (data that does not fit)	In the foraging loop the searching, filtering, and extracting are data driven and search for information and relations is goal driven	Information, cues, goals
	Use of cues	Data, data representations, residue (data that does not fit),	Data and cases	Mostly information
	Sensemaking activities	Searching for data representation, encoding data, identify residue, shift representation to include residue, use encoded representations	Schematize, building a case and present case are the data driven and search for evidence, support and re-evaluate the question driven processes.	Meaning making, searching for cues, formulating expectancies, beliefs and hypotheses, comprehension
Understanding as process outcome	**Sensemaking process outcome**	Data representation structure,	Actionable knowledge or action	Understanding, sub-sets of understanding, actionable knowledge, confirmed situation frame
	Linking sensemaking to action	Not described	Outcome determines action	Outcome is actionable knowledge

Table 3-3 - Comparison of sensemaking literature (continued)

Process structure and elements

The commonality of all presented theories and models is that the process begins with a sensemaking context (occasion) and comprises specific activities to create and use inputs – just like any other process - to gain understanding. Weick, Klein and Ntuen list a number of sensemaking contexts, especially ambiguity and uncertainty, which Dervin calls gaps. Although Weick and Dervin describe no formal process steps or sequences that people follow, they both distinguish between creating and using cues/information. Dervin as well as other authors in the information processing and systems domain focus on information or data as process input. Weick and Klein mention that input in any form will be used if it serves the purpose, e.g. maps, routines, behaviour. They also emphasise the importance of assumptions and hypotheses which are mental constructs and can be important reference points to build up sense. This indicates that the process might comprise many stages, reflected in form of loops or cycles of going back and forth between creating new input, constructing intermediate output and refining it (Klein, Russell et al., Pirolli and Card). This is reflected in the literature where Russell et al. described the sensemaking process as a learning loop complex where data representations are improved. Building on this model Qu and Furnas argued that learning happens along the way of the process. Weick calls this developing a larger sense from small structures and the data/frame theory comprises activities to elaborate a frame. Thus, the sensemaking process might occur in stages, reflecting a transition from limited to improved understanding. To use an analogy, the sensemaking process might be pictured as a bus route. It has a beginning, an end, goes back and forth and most importantly has many stops in between. These stops might be outputs of intermediate process stages, reflecting specific understanding that changes in the following, for better or worse. This would indicate that specific parts of a process have a specific purpose, reflected in each intermediate outcome. Pirolli and Card argued that there are data-driven and goal-driven parts of the sensemaking process, which reflects different purposes. However, no research could be identified that investigated the sensemaking process with a focus on its structure, its process stages and linking it to understanding as it develops. Moreover, none of the models originate from the fire fighting domain. This is the gap in literature that this present research seeks to address (gap 2).

Taking the above arguments the elements of sensemaking process should be the following: sensemaking context (perhaps including changes along the process), cues (inputs), activities (cue creation and cue use), output in form of (intermediate) understanding. If the process occurs in several stages, then a particular structure of the process and the sequence of element combinations might be suspected. This is indicated in sensemaking process models in form of loops or cycles, and going through a specific sequence of activities (see Table 3-2 and Table 3-3). However, the literature also indicates that sensemaking is a highly individual and subjective process. Thus, different individuals might follow different process structures. In the bus route analogy this would mean that there are different routes to get from A to B. Rather than assuming that people always take the same route an investigation of sensemaking should first establish what routes people use and whether there are route patterns. So far, existing models provide an aggregated view of sensemaking processes that individuals use. The limitation of a single, integrated model is that variations in the illustrated process are difficult to show without making the model unclear. To keep richness and detail, each variation and its application context should be shown and explained individually before being combined in one single model. This approach was taken by Klein (1998) when he illustrated variation 1, 2 and 3 of his Recognition-Primed Decision Model before presenting an integrated version. Moreover, existing models do not originate from the emergency response domain. Thus, one cannot be sure if the people in incident response follow the process steps suggested in existing models. Thus, we have limited understanding about the sensemaking process structure followed in the emergency response domain, if process structure variations exist, how they might look like and what their purpose is. This constitutes gap 3.

Process outcome

The outcome of the sensemaking process is described in a variety of ways, e.g. understanding (for decision making, anticipation, take action), meaning, ability to act, actionable knowledge, action. Most authors see understanding as the basis to determine further action. Only Weick and Klein stress that if there are no cues or data available to be used for sensemaking, then action precedes understanding because cues/data have to be created to have an input for the process.

However, the literature review revealed that the focus of sensemaking research is not on understanding as process output. Even the literature on fire fighting describes what individuals need to understand, and thus make sense of, rather than what is actually understood. The literature on understanding and learning suggests that there are degrees or levels of understanding, manifested in specific abilities. This insight in combination with the argument of the previous paragraphs that there might be multiple intermediate outputs in the sensemaking process, could suggest that understanding improves or at least changes along with process stages. However, to date there is no research that addressed the question what is actually understood as process outcome and how understanding specifically evolves in the stages of the sensemaking process. This constitutes a gap in current literature (gap 4).

3.4 Research gap summary

The following research gaps have been identified in the previous section 3.3:

Gap 1: Limited understanding of how sensemaking context develops in the sensemaking process, i.e. if, how, why it changes and what the consequence is.

Gap 2: Limited understanding of what stages exist in the sensemaking process and how they are linked with evolving understanding.

Gap 3: Limited understanding of what sensemaking process structure people in the emergency response domain follow, what process variations exist and what their purpose is.

Gap 4: Limited understanding of what is understood at intermediate stages and the end of the sensemaking process, if different levels of understanding can be identified and how understanding evolves along the process.

The methodology to carry out the research and address the above described gap is presented in the next chapter.

4 Methodology

This chapter aims to convey

- The overall research process (see section 4.1),
- The adopted philosophical perspectives and research strategies (see section 4.2),
- Which methods were used in past sensemaking research (see section 4.3),
- What the adopted research design looked like (see section 4.4), in particular what the research questions were (see section 4.4.1) and what strategy and methods were seen as appropriate to answer them (see section 4.4.2),
- Why the 9/11 event was suitable for this study (see section 4.5),
- What the sample was and how interviews and episodes were selected (see section 4.6),
- What specific steps were followed to analyse data (see section 4.7).

4.1 Overview of research process

The purpose of this section is to illustrate the major steps of the overall research process.

As described in Chapter 1, the researcher's personal experience was the motivation for the research and triggered the question that guided the study development. An exploratory phase was used to narrow down the scope of the research, identify useful study settings, test and refine data collection methods and analysis methods, and identify requirements for the main study. The phase included data collection in six emergency exercises and through additional interviews. Insights from data were used to guide the following steps. Moreover, an initial literature review was conducted.

The research focus was now on the fire fighting domain and aimed to investigate sensemaking processes of senior officers of the New York Fire Department during their response on 9/11.

Insights from this project phase resulted in the discovery of specific process patterns. This required the formulation of a second research question to investigate the underlying mechanisms of the identified regularities.

At this time an up-date of the research design and the literature review was required. The research design as described here in chapter 4 is the overall design used to answer RQ1 and RQ2.

The next project phase included re-analysis of the 9/11 data for theory building on underlying sensemaking process mechanisms.

The results were then presented to experts from the Fire Service College to collect feedback.

4.2 Philosophical perspectives and research strategy

The research strategy was a combination of abduction and retroduction from the perspective of constructivist realism. The following paragraphs briefly compare philosophical perspectives before social realism, abduction and retroduction are explained.

In order to create new knowledge it is necessary to describe the logic of the research process, its underlying assumptions and approaches taken. Five interdependent concepts have to be considered: research question, research strategy, research paradigm, ontological and epistemological assumptions (Blaikie, 2007). The strategy to answer research questions needs to be suitable (Blaikie, 2007) but has underlying assumptions about the nature of reality (ontology) and how the researcher can know about this reality (epistemology) (Easterby-Smith et al., 2002). The questions about ontology and epistemology are combined in a research paradigm, which is a "*basic belief system or worldview that guides the investigator, not only in choices of method but in ontologically and epistemologically fundamental ways*" (Guba and Lincoln, 1994:105). Although there is no 100% right or wrong answer the researcher needs to clarify his philosophical position (Guba and Lincoln, 1994) because it informs the research design in terms of useful and working methods (Easterby-Smith et al., 2002).

The four research paradigms shown in Table 4-1 (based on and adapted from (Blaikie, 1993; 2007) comprise different views on the nature of reality, how the researcher can know about it and the typically used research strategies. Two opposite assumptions about the nature of reality exist with many finer distinctions in between (Blaikie, 2007). In the realist ontology reality exists independently of the observer whereas in the idealist ontology reality is a construct of thought processes and thus an internal reality. With regard to epistemology, the two extreme positions are that of empiricism and constructionism. In the former the researcher is using his senses to objectively observe reality and what he experiences is facts that are true. In the latter the researcher needs to study language, meaning, motives and concepts that people use to construct their reality in which he is involved and becomes part of. The ontological and epistemological assumptions come together in different combinations in research paradigms.

Positivism, critical rationalism and interpretivism

Positivism is the classical view of how research in the natural sciences was possible but its applicability to the social sciences is rejected. The researcher objectively collects true facts to construct hypotheses which are tested against further observations to develop universal laws that describe the relationship between variables. The gained knowledge is absolute and generalisable.

Critical rationalism rejects the view that objective, value free observation is possible (cautious realist) because the researcher always has a theoretical view that might influence observation. Thus, theories need to be constructed that could explain a phenomenon, followed by testing hypotheses against data in deliberate attempts to falsify that theory. The strategy of deduction is associated with this paradigm.

Research paradigm	Positivism	Critical Rationalism	Social realism (structural realism, constructivist realism)	Interpretivism
Ontology	Naïve or shallow realism	Cautious or critical realist	Depth realist/subtle realist	Idealism
Epistemology	Empiricism, objectivism	Falsification	Neo-realism/ constructivism	Constructionism
Knowledge	Absolute	Tentative	Tentative	Relative
Research strategy	Inductive	Deductive	Retroductive	Abductive
Aim	Universal laws for description and explanation of characteristics and patterns	Test theories to eliminate wrong ones, test hypothesised against data	Find out underlying mechanism to explain observed regularities in specific context	Description and understanding of social life from actors' motives and accounts
Start	collect data, generalise	identify pattern to be explained, construct theory and deduce hypotheses	document and model pattern, create hypothetical model of mechanism	discover everyday lay concepts, meanings and motives; create technical account from lay accounts
Finish	use laws to explain more observations	test hypotheses by matching them with data	find the real mechanism by observation or experiment	develop theory and test it
Exploration (what question)	Major			Major
Description (what question)	Major			Major
Explanation (why question)	Minor	Major	Major	
Prediction (what question)		Major		

Table 4-1 - Overview of philosophical perspectives and research strategies

A theory is only corroborated and tentative, one cannot claim its universal truth because it might be falsified at a later stage.

In the interpretivist paradigm the possibility of multiple, socially constructed realities is acknowledged (Robson, 2002). This means that social actors might attribute different meanings to actions or situations because they constantly engage in interpretation. Thus, this paradigm rejects the positivist view of one single, external reality. Studies need to focus on the origin and context in which these meanings are embedded (Schwandt, 2003). Using an abductive research strategy the scientist can build theory from the interpretations, intentions and meanings that social actors use, e.g. by developing abstract categories and concepts from original accounts for typical actors, situations and actions that explain a phenomenon (Blaikie, 2000).

Social realism (structural and constructivist)

Social realism takes the middle ground by combining and refining some assumptions of the positivist and interpretivist paradigms. Many of the situations studied in social science are not embedded in a closed system where constant conjunctions allow for clear statements about causal relationships between variables, which is the positivist view (Tsoukas, 1989; Williams and May, 1996). Rather, we find an open systems environment where things relate in non-linear, unpredictable ways and people base actions on constantly evolving interpretation and ideas of what is going on. Thus, the positivist view of constant conjunction and way of deriving explanations needs adaptation for the social sciences and needs at the same time to acknowledge that people might socially construct their reality. This is achieved in the paradigm of social realism which is based on the work of Bhaskar (1975) and Harré (see Harré and Secord, 1972). Here, explanations are not found in the observed reality and its constant conjunction (which is the assumption of empiricism) because "*constant conjunction really depends on the level of description: that is, what you look at and how you look at it*" (Williams and May, 1996:82). Williams and May (1996:83) explain this with the example of the empiricist who would explain the delay of a train as follows: "*if the 8.55 train has arrived late on a number of occasions, the explanation for it arriving late on a particular day is that it always does. Here, the explanation is build up of singular, but alike events*". However, it is very likely that a number of different causes explain the delays on different days. Consequently, the cause is independent from the observed phenomenon and the researcher, and cannot be found by just observing a regularity. A phenomenon becomes researchable by adopting the perspective of a multi-layered ontology (depth realism) with three domains: in the *empirical domain* events can be observed, in the *actual domain* events occur no matter if the researcher is present to observe it or not, and in the *real domain* the structures and mechanisms that cause the event can be found (Blaikie, 2000). For these reasons the "*aim of Social Realism is to explain observable phenomena by reference to underlying structures and mechanisms*" (Blaikie, 2007:181). Thus, in social realism the researcher's work does not end with the discovery and description of a regularity but goes further by asking why these regularities happen and what their underlying cause is. This is reflected in the retroductive research strategy as one way to answer "why" questions.

A number of authors have described the concept of underlying structures and mechanisms as well as the two opposing views of Bhaskar (1975) and Harré (see Harré and Secord, 1972) on where these can be found (see Blaikie, 2007; Robson, 2002; Blaikie, 2000; Tsoukas, 1989; Williams and May, 1996; Chia, 2002).

There might different causal mechanisms for an event, they might not be active all the time and even cancel themselves out. Not all causal mechanisms manifest themselves in the empirical domain but could well be theoretical constructs.

If the cause of an event does not depend on the observed regularity, then it has to be regarded as a tendency, which might well interact with other tendencies (Williams and May, 1996). "C*ausal powers operate as tendencies whose activation, as well as the effect(s) of their activation, are not given but contingent*" (Tsoukas, 1989:553). Thus, the right conditions need to exist or be created to be able to observe it in the empirical domain or actual domain (as event). As the mechanisms might be interrelated they could well have emergent powers, which means they produce an effect together and the regularity cannot be explained by decomposing and reducing it to components (Chia, 2002). This means that the wider context in which the regularity and the causes are

embedded has to be incorporated into the research, e.g. describing constraints. This reflects the view of complexity science where a complex system cannot be understood by explaining its components because of self-organising and emergent properties. The same thing never happens in the same way twice, so the observable regularities can only ever be tendencies. However, this does not mean that the underlying mechanisms and structure cannot be described.
From a realist perspective, knowledge advances by building theories about the underlying mechanisms that produce observable effects. However, it has to be accepted that these theories are about reality (closely reflect reality) but not reality itself (Chia, 2002).
The process of investigation consists of empirical studies to describe the patterns or regularities of a phenomenon, followed by theoretical studies to explain the underlying cause for the patterns. This means that the focus of the research can be on both real as well as theoretical entities. A proposed theoretical mechanism needs to be able to explain the regularity in the phenomenon. Bhaskar and Harré developed different views about the nature of causes and where to find them. Bhaskar's view is referred to as structural realism because he argued that social structures and relations influence, enable and inhibit human action. For example, power relations and status might be underlying structures that explain why women have limited chances to become part of male-dominated top management. However, Harré argued that people's actions are causal mechanisms, which might lead to specific social structures. Actions are related to cognitive equipment and resources, which people use to construct their world. Their thinking processes and the images they construct of social situations are the cause for observable events. This reflects a constructionist position and is, thus, called constructionist realism. Consequently, depending on whether one follows the structuralist or constructivist version of realism, explanations for observed regularities are either sought in social structures or cognitive mechanisms.

Locating sensemaking research

Sensemaking research aims to understand how individuals or groups ascribe meaning to situations, what the situations mean to them, and how people construct what they perceive to be reality. Thus, sensemaking is located in the social-constructivist perspective (Craig-Lees, 2001). It is argued here that even from the perspective of information processing/analysis and cognitive processes sensemaking is an individual and subjective process that involves interpretation to arrive at some kind of sense.

Adopted research strategy and philosophical perspective

Based on the view that people construct their reality and meanings, the positivist, critical rationalist and structural realist paradigms are rejected. Given that the first research question was to study and describe the sensemaking process from the viewpoint of individuals, an abductive research strategy based on the interpretivist paradigm was adopted. This means that the sensemaking process was reconstructed based on the accounts and language of interviewees. The process becomes an abstract means to describe how actors themselves create understanding. This would allow for rich descriptions of people's reality. However, as described earlier, the discovery of specific patterns in the sensemaking process led to a second research question, i.e. an attempt to explain why these patterns occur. Thus, the retroductive research strategy was adopted at this point to build theory on underlying mechanisms that might cause these patterns. This means that for this research the philosophical perspective of constructionist realism is adopted, which allows for abductive research in the first, empirical phase and then a move to retroductive research strategy for theory building at the second stage. The aim was not to develop a comprehensive, formal theory that explains a wide range of phenomena and is applicable in many contexts. However, underlying mechanisms can take the form of theoretical constructs.

4.3 Methods in sensemaking research

This section demonstrates which methods are used in sensemaking research, before the research design and method adopted by the researcher is presented.
Section 4.3.1 reviews methods used in past research, section 4.3.2 describes the researcher's insights based on the exploratory project phase described in chapter 2.

4.3.1 Past research

Weick researched sensemaking in the context of human organising activities as well as conditions under which sensemaking collapses mainly based on historical records, official documents and reports. This includes his study on industrial accidents (Weick, 1988), the crash of two airplanes at Tenerife based on official reports and cockpit conversations (Weick, 1990), and sensemaking in wild land fire fighting based on historical records, testimonials and investigation reports (Weick, 1993; 1995a). Smith (2000) applied Weick's seven characteristics of sensemaking to explain confusion in the airplane cockpit before the Kegworth air crash based on investigation reports and cockpit conversations. It should be noted that the sample size in these studies is very small (about 4-10), which reflects the number of operators in control room, pilot crews and small groups of fire fighters.

Craig-Lees (2001) wrote that the unit of analysis in sensemaking research needs to be the individual and that the data to be collected might be from in-depth interviews or narratives/stories. Barton and Sutcliffe (2009) used semi-structured interviews with 28 wild land firefighters for their study. They collected narratives where interviewees reported on their experience from beginning to end of a specific fire event. Using this narrative approach they were able to collect detailed personal experiences with plenty of behavioural information. This proved to be a useful approach to avoid "*generalized responses which may have been biased towards 'by-the-book' actions. We were less interested in what individuals were supposed to do than what they actually did*" (Barton and Sutcliffe, 2009:1334).

In the context of information and communication studies by Dervin (1984) who developed a method to study sensemaking. Micro-Moment Time-Line Interviews are in-depth interviews in which the following steps are covered:

1. Investigating step by step in great detail what happened during the situation
2. Enquiring gaps for each step of the situation
3. In depth analysis of each gap experienced
4. Investigate how each gap was closed

However, some adaptations of this very detailed and time-consuming method have been made. For instance, the abbreviated time-line interview focuses on one significant

situation, gap and use (Dervin, 1992). Several variations of the approach exist, each adapted to the specific purpose of the study.
Also in the context of information processing, analysis and visualisation studies a variety of methods is used. Amongst these are cognitive task analysis and verbal protocol analysis (Pirolli and Card, 2005), knowledge structuring tools (Russell et al., 1993), observation and computer logging (Takayama and Card, 2008).

To develop their Data/Frame theory, Klein and associates used the critical decision method (CDM), interviews adapted to sensemaking, archival analysis and coding of think-aloud protocols (Klein et al., 2007a; Sieck et al., 2007). CDM is a variation of the critical incident method (Flanagan, 1954) used for cognitive task analysis (see Crandall et al., 2006).

In the fire fighting domain a number of field studies with the focus on developing technology to assist sensemaking exist. Following an ethnographic approach, observations, field notes and video recordings, interviews, documents, and communication recordings were used (Dyrks et al., 2008; Landgren and Nulden, 2007; Landgren, 2006; Jiang et al., 2004; Landgren, 2005).

4.3.2 Exploratory research by the researcher

As described in chapter 2, the researcher took part as observer or participant in six exercises and conducted six interviews to learn about potentially useful settings and methods for this research. 15 requirements for the main study were derived.
The exercises included table-top exercises, real-time simulations and full-live exercises in contexts ranging from business continuity, to aircraft crash, aircraft evacuation and incident command in the fire services.
It was learned that the setting needs to be sufficiently challenging to produce sensemaking occasions, even if the study participants are professionals. This requires exceptional or unusual events. Observation and open ended questionnaires were ruled out as useful data collection methods. Especially, since even the open ended questionnaires resulted in the return of very short narratives, which was not helpful to gain detailed insights into sensemaking processes. Interviews were identified as preferred data collection method.
However, the experience from conducting six interviews with officers of the UK Fire & Rescue Services was mixed. Although detailed accounts of sensemaking during incidents were obtained, analysis resulted only in an inventory like table that showed sensemaking process elements. This gave only a fragmented view of the sensemaking process. Moreover, problems of recollecting incident details from memory, probably due to time passed since the incident, were encountered.
This left the researcher in the position of having used the preferred data collection method but still not being able to get the desired results. A change in the approach towards data collection and analysis was required to overcome these problems. The methods that were then used are described in the remainder of the chapter.

4.4 Research design and methods

Blaikie (2000:39) defined research design as "*the process that links research questions, empirical data, and research conclusions*". Thus, this section will start with a review of the research problem and questions. This is followed by an argument for the appropriate method (which is in line with the adopted philosophical perspective) to answer the research questions. Section 4.6 and 4.7 will describe data collection and analysis procedures.

4.4.1 Research problem, research questions and clarification of terms

In Chapter 1 the research problem was described. It was stated that the sensemaking process is vital for understanding situations and events in an emergency. The literature review (Chapter 3) confirmed this view and stated four research gaps, resulting in two research questions (RQs):

RQ1: What process do individuals follow to make sense of events during an emergency?

RQ2: Why do stages occur in the sensemaking process?

Sensemaking was defined in Chapter 2 as: "*the deliberate attempt to understand events"* (Klein et al., 2007a:114).

Sensemaking process is defined here by the researcher as: a sequence of activities, initiated by a trigger, that use some form of input and may or may not transform it into some kind of output.

Event is defined here by the researcher as: a situation or occurrence that requires sensemaking.

Emergency is defined here by the researcher in the context of Fire Services as: a situation that requires the responsive action by the Fire Services.

RQ1 required a descriptive answer. Craig-Lees (2001:515) commented that "*given that there is a beginning and end to each act of sense making (although this may not be the case) the use of the term "process" may be legitimate. But unless elements/components are identified, how they relate cannot be assessed nor the process examined*". This means that the answer for this research question needed to comprise a description of the sensemaking process elements and how they relate. These elements would then be combined in process diagrams that illustrate the overall process, process steps, elements and their relationship.

RQ2 required an explanatory answer. At this point the retroductive research strategy was adopted to focus on theory building about the underlying mechanisms that might produce, and therefore explain, the process stages.

4.4.2 Final research strategy and Grounded Theory approach

This section explains how the researcher decided to adopt the approach of modified constructivist grounded theory, which fits with the adopted philosophical perspective of constructivist realism as well as the abductive, retroductive research strategy.

A general distinction between research designs is based on whether the study is quantitative or qualitative in nature. Whereas experiments are usually associated with quantitative research, case studies, ethnography, grounded theory, and action research are usually associated with qualitative studies (Robson, 2002). However, the researcher should be guided mainly by the question which methods of data collection and analysis are suitable to answer the research questions. This might result in mixed designs.

The final research strategy described here is the overall strategy which became only clear once both research questions had been developed. Sitting in the constructivist realism paradigm, the overall strategy to answer both research questions was abductive for the first part which led to the observation of a specific regularity and then retroductive for the second part with the objective to find explanatory mechanisms for the observed regularity. As Blaikie (2007) argued, the combination of abductive and retroductive strategy is in line with Harré's (see Harré and Secord, 1972) perspective of constructivist realism. The starting point for the research is to use people's accounts and derive descriptions of the phenomenon from their point of view. The observed regularity and its description complete the abductive part but is only the beginning for retroduction to find answers to why the regularity occurs. Thus, the empirical description of the studied phenomenon is followed by theory-building studies. This corresponds with empirical first-order analysis and moving to a higher level of abstraction in second-order theoretical studies.

Based on the philosophical perspective, research questions and strategy outlined above, two possible methodologies for answering the research questions are case study (Yin, 2009) and Grounded Theory (Glaser and Strauss, 1967). Both allow for descriptive, explanatory research and theory-building. When deciding whether the case study methodology is suitable the researcher needs to consider three criteria. When the research question is a "how" or "why" question, the case is about a contemporary event and the researcher has no or little control over it, then case study is a suitable method (Yin, 2009). However, at the beginning of this study the research question was a "what" question and it was not anticipated that a "why" question would follow. For this reason a case study was not considered and instead the grounded theory approach chosen, which fits well with the constructivist perspective, abductive strategy and the type of research question.

Grounded Theory, developed by Glaser and Strauss (1967), is "*a qualitative research method that uses a systematic set of procedures to develop an inductively derived grounded theory about a phenomenon*" (Strauss and Corbin, 1990:24). A mixed method approach can be used for data collection and analysis. Theory development involves multiple loops of data gathering, constant comparison of multiple instances of the same event, identifying patterns in the data, creating conceptual categories and integrating these through establishing relationships (Easterby-Smith et al., 2002; Locke, 2001).

However, Glaser and Strauss developed different views on how Grounded Theory is to be applied. Glaser (1992) focuses on deep interaction with the data to develop concepts and links between those through constant comparison of different instances of the same phenomenon. He does not prescribe a detailed process but deep interaction and immersion in the data will lead to the emergence of patterns that can be developed further into theory. Strauss and Corbin (1990) emphasise the need for a structured coding process to reveal patterns in the data. Open coding for data labelling and category development is followed by developing category properties and dimensions, which are not limited to what is found in the data. Axial coding and the use of a paradigm model lead to linking categories based on causal conditions, phenomenon, context, intervening conditions, action strategies and consequences.

Charmaz (2003) reports on the ongoing debate on grounded theory and criticised that it makes objectivist, positivist assumptions about reality. The above citation indicates that it is an approach that uses induction, which fits the description of a positivist perspective. This would not be in line with the perspective adopted in this research. Charmaz (2003) proposed a constructivist grounded theory that takes the meanings and experiences of people's constructed realities into account by reporting on their point of view. It acknowledge that we cannot study the full extent of reality but only slices of it, captured in episodes on people's experiences. The constructivist grounded theory "*does not seek truth – single, universal and lasting. Still, it remains realist because it addresses human realities and assumes the existence of outside worlds. However, neither human realities nor real world are unidimensional*" (Charmaz, 2003:272). The research result is a demonstration how people construct their realities, rather than their actual reality. As such, the theory is tentative as "*causality is suggestive, incomplete, and indeterminate in a constructivist grounded theory*" and "*hypotheses and concepts offer both explanation and understanding and fulfil the pragmatist criterion of usefulness*" (Charmaz, 2003:273). The approach is flexible as analysis can be modified as research continues and is durable as it accounts for variation. People's close experience and feelings need to be captured in the stories they tell, which calls for rather free-flowing accounts rather than the researcher constraining and limiting response by framed questioning. These subjective experiences and feelings need to be reflected in the coding structure. However, it might be that no overarching theme emerges from the coding categories.

Partington (2000; 2002) wrote about the use of grounded theory in research on people's cognitive mechanisms. In the context of managerial behaviour studies, he used the stimulus – organism – response (S-O-R) model (Ilgen and Klein, 1989) as basis to modify grounded theory so that cognitive processes of meaning creation are actively considered. He simplified Glaser and Strauss' original paradigm model and conditional matrix for coding data and moved to a focus on mechanisms underlying cognitive behaviour by proposing the following steps: code and develop categories for stimuli and activities, visually represent relationships between them, theorise about underlying mechanisms, develop theory while testing and modifying codings. Thus, his version is situated in the domain of realism and is also in line with the retroductive research strategy. His simplified paradigm model of "environmental stimulus → cognition → management action" will be adapted for this study to provide one part of a theoretical framework that is used to guide the coding process (see section 4.7.1).

A flexible research approach was required for topic development and to inform the main study. The insights from data collection and analysis during the exploratory phase guided the next steps in the research. The development and changes of study setting, data collection method, data characteristics and level of detail in findings reflect this:

- from table-top exercises to real-time and full-live exercises, to real incidents
- from observation to questionnaire and interviews
- from short answers in questionnaires, to semi-structured interviews to free flowing narrative with a high level of detail
- from inventory-like, fragmented data on single aspects of sensemaking to detailed accounts on the whole process.

The grounded approach was suitable to let the data and insights lead the way and allow the topic and insights to evolve.

To summarise, modified constructivist grounded theory is used in this study because it fits with the adopted philosophical perspective of constructivist realism as well as the abductive, retroductive research strategy.

4.5 The selection of Fire Service Response on 9/11 as study environment

The experience of the Fire Service incident command exercises as well as having Weick´s approach of looking at past events in mind, the researcher searched for well documented fire events. The search quickly focused on 9/11 because the event is well documented and a wealth of material is available.

Since a number of potential data sources were available, the researcher went through a process of elimination to ensure that the best possible data was chosen for this study. As can be seen in Table 4-2, the data sources considered for this research included a public inquiry report, documentaries, biographic material as well as interviews.

With exception of the interviews from the NY Times archive other potential data sources were excluded because a lack of detail did not allow reconstructing sensemaking processes.

Potential data source	Description of data source	Researcher decision on data source
Public Inquiry Report and TV documentaries on the Kings Cross Fire, e.g. (Fennell, 1988)	TV documentaries do report on the timeline of events and investigations into causes of the fire. The Fennell report (1988) does not comprise comprehensive statements from Fire Service personnel.	Exclude data source. No firsthand accounts on sensemaking available. Therefore, no reconstruction of the sensemaking process possible.
9/11 documentary, e.g. Hanlon et al. (2002)	Cameraman accompanied Fire Chiefs during the 9/11 response. Pictures and fragmentary conversation from command post inside the World Trade Center available.	Exclude data source. Would have to be regarded as data obtained through observation, which was ruled out as data collection method. Audible conversations too short to reconstruct sensemaking process.
9/11 biographies, e.g. Picciotto (2002)	Books telling the story of individual fire fighters or commanders during the 9/11 events.	Exclude data source. Often incoherent fragments and not enough detail to reconstruct sensemaking processes. Often written a long time after the event.
9/11 Incident logs or timelines of fire service response, e.g. McKinsey & Company (2002)	Incident logs and timelines document what happened, movement of resources and decisions	Exclude data source. The incident log from the incident command post was destroyed and therefore not available. The timeline provides no useful data to reconstruct sensemaking processes.
NY Times 9/11 oral histories archive (The September 11 records, 2005)	Interviews with all members of the FDNY on their experience of the 9/11 response.	Chosen as data source. Level of detail provided in the interviews allowed reconstruction of sensemaking processes. The data also fulfilled requirements derived from chapter 2.

Table 4-2 – Potential sources of data for this study

It was also checked if the event qualifies for the research based on the 15 criteria for the main study, derived from the preliminary studies to scope the research (see chapter 2 for the requirements and the following Table 4-3).

Requirements 1-5 refer to characteristics that an event should have to be useful for this study. All of these requirements are fulfilled as the following paragraph demonstrates. The FDNY response to the events on 9/11 at the World Trade Center is about a real incident to which professional fire fighters responded. As demonstrated in the introduction (see chapter 1) it was an exceptional, extreme case. The Fire Services had never had to deal at the same time with 2 high-rise fires of that magnitude before and never experienced that one incident requires the coordination and response of hundreds of people. It was necessary for the commanding officers to understand the current situation and how it might develop to prepare a response.

Requirement check for the studied event	
Requirements from Chapter 2	**Requirement check for 9/11 events**
1 - High pressure scenario / a real incident / exceptional event / no previous experience of the event / required to generate sensemaking occasions	Fulfilled: Real incident, exceptional event, not experienced before, high pressure on incident responders
2 - No opportunity to avoid decision-making or taking actions.	Fulfilled: Many operational decisions had to be taken by commanders; postponing or not taking a decision was not an option
3 - Limited opportunity to solve sensemaking problem by group discussion preferred.	Fulfilled: Cannot be judged precisely; many decisions are made at the command post after group discussions. However, the interview passages used were all chosen based on individual not group sensemaking
4 - Main focus of the event/exercise should not be on organisational basics / getting operational	Fulfilled: Not an exercise. Setting up the command structure and get operations going is part of the task. However, the interview passages used do not focus on operational basics.
5 - Participants preferably professionals to avoid previous point 4.	Fulfilled: All FDNY responders are professional firemen. Senior officers were chosen as sample.
Requirements for data collection	
Requirements from Chapter 2	**Requirement check for 9/11 events**
6 - Comprehensive questionnaire	Not used and not required
7 - Interviews should be the preferred data collection method.	Fulfilled: Already existing interviews, conducted by the World Trade Center Task Force, were used as data source
8 - Access to individuals needs to be ensured.	Not used and not required
9 - Observation is not a useful for data collection method.	Not used
10 - Focus on one or two scenarios in depth.	Fulfilled: 9/11 is event that is studied in depth
11 - Preferably large sample size to detect patterns.	Fulfilled: 59 text passages from 21 interviews were used, varying between 1 paragraph and 2 pages
12 - If a questionnaire is used then the sample size should be large.	Not used
13 - Rich descriptions of individuals´ experience are required	Fulfilled: Interviews vary in length between 5 to 30 pages
14 - Sensemaking should be studied from the perspective of the individual as they construct sense about the same challenge in different ways	Fulfilled: All interviews are about the same event. The same situation is described by different interviewees from their point of view
15 - Described incidents should be recent events to improve chances of obtaining detailed reports	Fulfilled: Interviews were conducted between 1-3 months after the event.

Table 4-3 - Matching study requirements from Chapter 2 against 9/11 FDNY response

It was a real-life setting characterised by uncertainty. Dealing with a novel event is likely to trigger sensemaking processes that can be reported on. The speed of situation development, the magnitude of the incident and the fact that emergency services had not dealt with a case like this before led the researcher to believe that responders faced novel events during that day, that triggered sensemaking on various occasions and which could be reported on. Many operational decisions had to be taken by commanders. Postponing or not taking a decision was not an option. Many decisions are made at the command post after group discussions. Thus, overall it cannot be ruled out that sensemaking problems were not solved within a group. However, the interview passages used were all chosen based on individual not group sensemaking. Part of the incident response was to set up the command structure and get operations going. However, the interview passages used do not focus on operational basics.

Requirements 6-15 concern methodological considerations. Requirements 6, 8, 9 and 12 were not applicable and the remaining ones fulfilled. The data source consisted of unstructured interviews. In the aftermath of 9/11 the World Trade Center taskforce conducted interviews with hundreds of members of the emergency services. These interviews were released in 2005 and are publicly available via the New York Times website, called *The September 11 Records* (2005). A collection of interviews with members of the New York City Fire Department detailing their experience of the day was used as data source. The style of interviews, which range between about 6 to 30 pages, is free-flowing narrative. According to Barton and Sutcliffe (2009) this is advantageous because people report on what they actually did, thought and (emotionally) experienced, rather than on what they were supposed to do. Also Craig-Lees (2001) wrote that narrative data is used in sensemaking research. The sample size (59 chosen text passages from 21 interviews) and amount of data was sufficient and detailed enough to reconstruct how people made sense of the events they experienced. The majority of interviews hold detailed descriptions, resulting in documents ranging from 5 to 30 pages. An advantage is that all interviews concern the same event. If the researcher had conducted interviews with individuals from the UK Fire & Rescue Services, it would have resulted in a range of incidents, varying in size, context and difficulty. With the present data sensemaking of the same situation can be studied from different responders' perspectives. The interviews were conducted several weeks after the event. Moreover, it was an extreme event. This improves the likelihood of detailed reports because the events stick in memory. Thus, requirements 13-15 from chapter 2 are fulfilled.

The process of elimination regarding potential data sources and applying the 15 requirements from chapter 2 were not the only safeguards to ensure data quality. The following paragraphs provide additional background about the nature and quality of the interview data.

In the aftermath of 9/11 the World Trade Center Taskforce, consisting of members of the FDNY, conducted interviews with hundreds of members of the emergency services. These interviews were released in 2005 and are publicly available via the New York Times website (The September 11 records, 2005). This was the data source for the research. The database is an archive of oral histories (about 12000 pages), told by members of the Emergency Medical Services (EMS) and the New York City Fire

Department (FDNY). These are detailed accounts in which responders describe in their own words their role, activities and experience of the response to the events at the World Trade Center on 9/11.

The purpose of the interviews was to create a historical record of what happened and identify possible learning points for incident response in the future (Dearstyne, 2007). Since the purpose of the interviews was neither to establish accountability of actions and decisions nor find parties to blame there is no reason to suspect that interviewees have provided untrue accounts of their experience. The interviews are free-flowing narratives of what individuals experienced that day, only occasionally interrupted by questions. These questions were mainly about which colleagues they had seen at specific points in time or locations. It was up to interviewees to choose what they report on and to what level of detail. Therefore, there was no reason for interviewees to hide details, deliberately distort data or provide untruthful accounts. Thus, the researcher had reason to believe that the accounts are true. Moreover, the interviews were conducted in the weeks after the event. Thus, the data is much more current and possibly more complete than other data sources, e.g. biographies or documentaries.

To summarise, the researcher has chosen the 9/11 interviews because of their usefulness and quality compared to other available data sources. The choice was specifically based on

- the process of elimination for potential data sources,
- the check against 15 criteria for the main study derived from chapter 2,
- the purpose of conducting the 9/11 interviews,
- the way in which the interviews were conducted,
- the choice of interviewees of what they report on and level of detail,
- the nature of the accounts provided, i.e. free-flowing narrative, and
- the level of detail provided in accounts.

Consequently, only one data source was used for the main study. Ideally, data triangulation is used to increase external validity of findings. However, triangulation could not be used in this case because of a lack of usable data sources on 9/11 (see Table 4-2). Using other data sources for triangulation was planned but these had to be excluded for data quality reasons as well (see section 8.8.2 for further explanations on data quality and triangulation).

The following section explains the sample structure as well as how interviews and text passages were chosen.

4.6 Sample, interview selection and text passage identification

The unit of analysis was the sensemaking process of individual persons who attempted to make sense of an event.

Figure 4-1 illustrates the number of available interviews on the New York Times database and how sample selection procedure reduced the sample size.

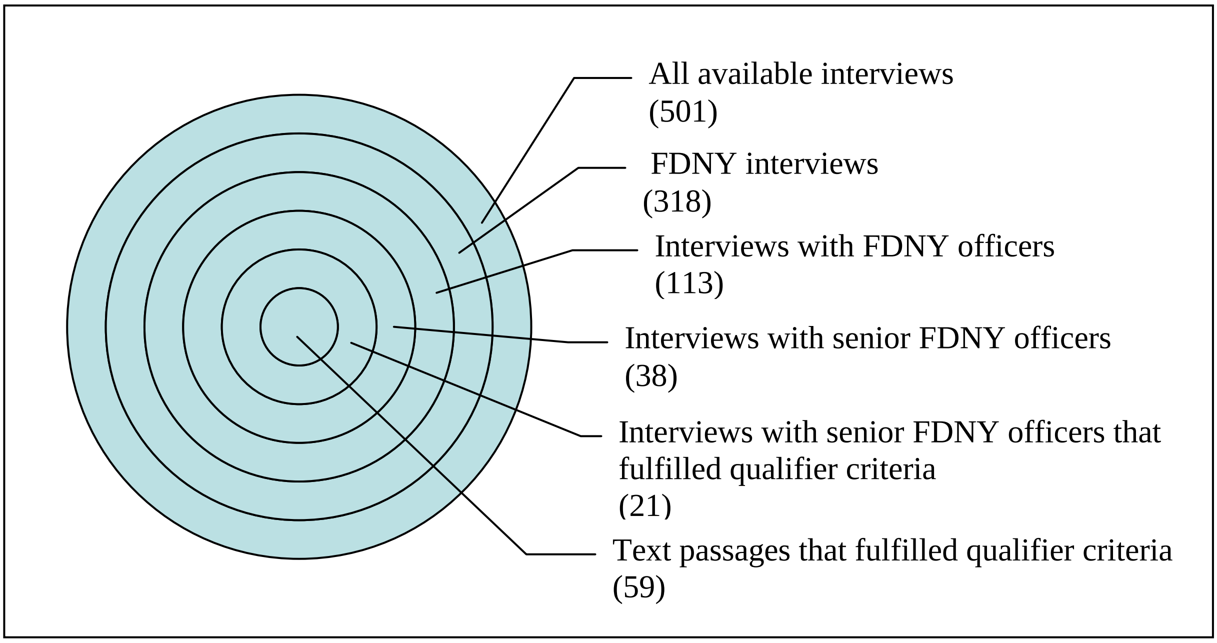


Figure 4-1 - Narrowing down possible interviews to text passages for analysis

Sample selection proceeded as follows: A total of 501 interviews were available on the New York Times database. These included interviews with Emergency Medical Staff as well as members of the New York Fire Department. The former were discarded and 318 interviews with members of the FDNY considered as the potential sample size. Next, all interviews with fire fighters were eliminated from these 318, which reduced the sample size to 113. The sample now consisted only of interviews with officers. Only interviews with officers were considered because the sensemaking task is mainly with crew leaders or the incident commander (Landgren, 2005). Next, the 113 interviews were cross read and the ones kept with either very high ranking officers or those who seemed to have obvious sensemaking challenges. This narrowed the 113 interviews down to 38. The following step was to use defined selection criteria for interviews and text passages (these are described on the following pages). Sufficiently rich descriptions of novel situations and corresponding efforts to understand them were required for the analysis. This selection procedure reduced the sample size from 38 to 21 interviews. From the 21 interviews 77 individual text passages fulfilled qualifier criteria (text passages are referred to as sensemaking episodes). They varied in length between one paragraph and two pages. The 77 episodes had to be reduced to 59 because the analysis process revealed that several episodes were too fragmented to allow reconstruction of sensemaking processes. The 59 episodes were the basis for data analysis. Appendix B1 shows a reference guide for sensemaking episodes. It shows from which interview (including page number) the episodes originate.

The selected 21 interviews were a total of 115 pages transcribed material. This was reduced to 59 episodes totalling 37 pages of transcribed, relevant and usable material. The sample size was smaller than the researcher initially expected. However, rather than trying to increase the sample size before starting the analysis process, it was decided to begin with the analysis. It was planned to see the results that can be achieved with the given sample and then make another judgement about potentially increasing the sample size. Data coding and analysis as well as unexpected findings that led to the second research question and subsequent additional analysis of the same rather than new data, consumed a substantial amount of time. By the time the analysis was finished, time constraints of completing the thesis did not allow to increase the sample size with subsequent additional analysis. Moreover, the feedback from experts at the Fire Service College on the results was encouraging. They commented that the findings reflect the sensemaking of incident commanders and are also applicable in the wider command context. This increased confidence in internal and external validity of findings. It meant that the developed theory was applicable, had explanatory power and was seen as fit by practitioners. For both reasons, time constraint as well as expert feedback, the researcher decided not to increase the sample size, based on the judgement that probably no substantial gains could be made from it.

The focus was on using interviews with senior fire service officers. Figure 4-2 shows the hierarchy of the operational structure of the NY Fire Department (based on Anonymous, 2010). It also illustrates the hierarchy of ranks from fire fighter to Fire Chief and Commissioner.

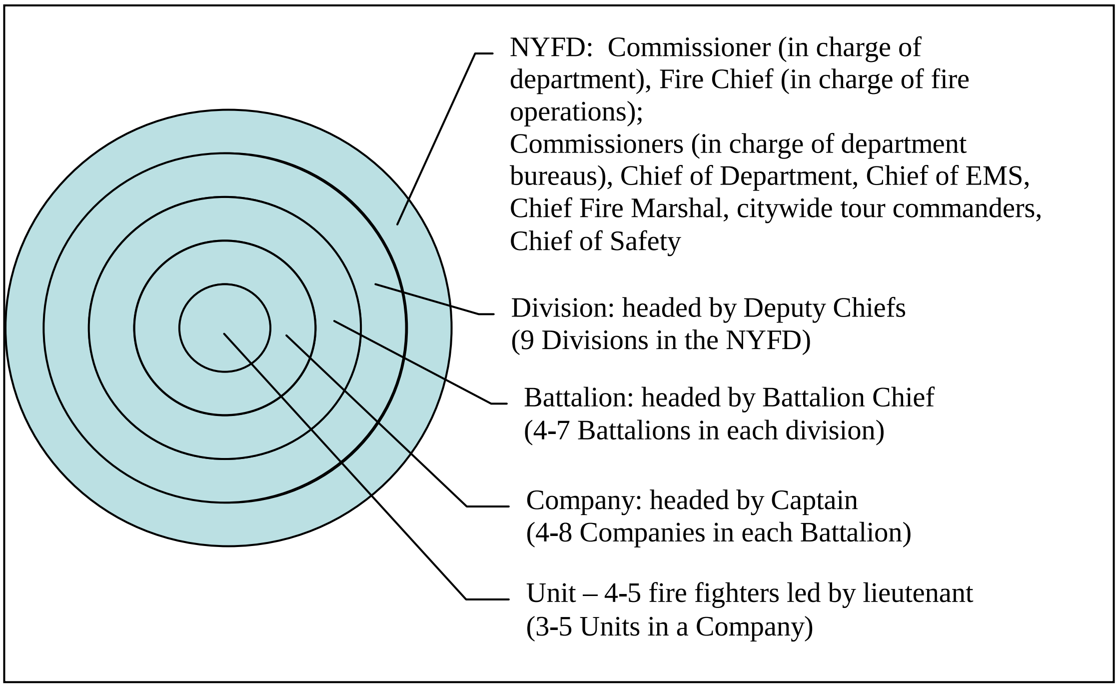


Figure 4-2 - Structure and ranks in the New York Fire Department (FDNY)

The 21 selected interviews reflect almost all officer ranks shown in Figure 4-2. The following ranks are reflected in the sample (in order from highest to lowest):
1 Chief of Department, 1 Assistant Commissioner, 1 Deputy Commissioner, 1 Deputy chief of division, 3 Chiefs (no nearer specification), 3 Assistant Chiefs, 1 Deputy Assistant Chief, 8 Battalion Chiefs, 1 Fire Marshal, 1 Lieutenant.
The following paragraphs describe the selection procedure for text passages on sensemaking within the interviews. The selection of relevant text passages was based on two requirements. First, a sufficiently complex event that defies immediate sensemaking needed to be found. This had to be characterised by qualifiers that indicate sensemaking processes (start, process and outcome) are required. Second, the text passage requires a sufficiently rich description of sensemaking activities and cues that allowed categorising and reconstructing the process. These requirements were derived from Weick (1995) and Dascal (1981).

Sufficiently rich descriptions of sensemaking were found in 21 interviews. To qualify as sufficiently rich an interview had to fulfil two criteria (see Table 4-4).

<table>
<tr><th colspan="2">Criteria and qualifiers for interview and text passage selection</th></tr>
<tr><th>Criterion 1</th><th>Criterion 2</th></tr>
<tr><td>Questions
• What are you talking about?
• Is this a joke?
• How is this possible?
• What is this?
• Which way is out(side)?
• Who are we getting these reports from?”</td><td rowspan="2">Descriptors of sensemaking activities
• It looked to me as if…,
• I thought this looks like…,
• I was trying to calculate…,
• I was trying to determine…,
• I figured…,
• I assumed…,
• Trying to get an idea...,
• Possibly…,
• Led me to believe…,
• Maybe…maybe…,
• Maybe I should…,
• In my mind I remember thinking…,
• I assumed that either…or…,
• I thought I would have a better chance…,
• I realised that I wasn’t able to…,
• Right away I suspected that…,
• My next thought was…,
• First I thought…,
• Starting to pay attention to…,
• I didn’t like that option because…,
• I remember seeing…,
• that was notably absent,
• My initial reaction was…I later realised that…,
• I was extremely concerned that…and then I would have to…</td></tr>
<tr><td>Not being sure what is going on
• I assumed…,
• I suspected…,
• I wasn’t sure…,
• I was worried about what was going on…,
• It sounded like…,
• …that surprised me,
• …not knowing what was going on,
• I couldn’t believe that…,
• We heard a rumble, we heard a noise, I heard a roar…,
• I didn’t know…,
• There was no way of telling yet…,
• There was a possibility of…,
• Just heard a loud, thunderous, rumble sound…,
• I could not believe what I was seeing”.</td></tr>
</table>

Table 4-4 - Criteria and qualifiers for interview and text passage selection

First, there had to be a sensemaking occasion, e.g. a situation that is not understood, triggers questions or needs clarification. Thus, the interviews were scanned for sensemaking occasions (in the following referred to as sensemaking context) using the ones identified earlier in the literature review, i.e. turbulence, complexity, novel cues noticed, information load and quality, state, effect and response uncertainty, surprise, ambiguity, unexpected events, absence of expected events and plausibility. These characterise the context of the situation or how an individual perceives a situation to be. For instance, a situation is perceived to be ambiguous because of multiple possible meanings. This does not mean that a person is in the mental state of ambiguity but his present understanding of the situation shifts to a low level. This triggers attempts to figure out a plausible meaning to reduce ambiguity and restore or improve understanding. Key words (qualifiers) in the interview data that indicated questions or situations in which interviewees were not sure what was going on are shown in the left column of Table 4-4.

The second criterion was a description of activities that individuals used to make sense of the situations identified through criterion 1. The qualifiers for text passages in relevant interviews are shown in the right column of Table 4-4. If the description was comprehensive enough to allow a reconstruction of the sensemaking process from the verbal report in the interviews, then the text passage was chosen for further analysis.

Many interviews did not fulfil both criteria or were not detailed enough to qualify for analysis. Many interviews comprised more than one text passage that qualified for further analysis. This resulted in the selection of 59 text passages (referred to as sensemaking episodes), varying in length between one paragraph and two pages, from only 21 interviews. These became the basis for data analysis.

How the sensemaking episodes were analysed is described in the next section.

4.7 Data analysis

This section comprises descriptions of underlying assumptions of data analysis (see section 4.7.1) as well as the procedure of interview analysis. This includes descriptions of coding procedure and category development for sensemaking challenges, context, activities, cues and cue types and how process diagrams were developed from the data (see section 4.7.2).

NVivo, a software for structuring, reduction and analysis of qualitative data, was used. It was chosen for three reasons. First, it was anticipated that the amount of data would result in a high number of codes, which is easier to create, change and analyse with a specialised software. Second, the software functionality suited the researcher requirements because data can be coded, queries can be run for analysis of text and codes and models created based on the developed coding. Third, NVivo was available for the researcher at no cost.

4.7.1 Assumptions and theoretical framework guiding the analysis

The analysis was based on the assumption that sensemaking is a process in which context acts as trigger (see e.g. Weick, 1995), activities (see e.g. Klein et al., 2007a; Sieck et al., 2007; Pirolli and Card, 2005)) and cues (Weick, 1995; Weick et al., 2005; see e.g. Starbuck and Milliken, 1988) are the main components that interrelate in some way and may produce an output.

Some of Dervin's (1983:7-8) assumptions about sensemaking research were also adopted:

- Information (cues) are always subjective, as it is related to observations by individuals;
- Sensemaking is connected to situation and context as well as past, present and future;
- Sensemaking research is bound to investigating the perspective of an actor (who makes sense of something).

These assumptions automatically direct the attention of the researcher towards looking for the above mentioned main components in the data. There may be more and other relevant components. However, based on insights from the literature review, the researcher focused on these.

Partington's (2000; 2002) simplified grounded theory paradigm model ("environmental stimulus → cognition → management action") was adapted to the context of this study as follows:

Sensemaking context as stimulus → use of sensemaking activities and cues → understanding (with possible subsequent action)

The focus for answering RQ1 was on the first and second part of the paradigm model. The focus for RQ2 was mainly on the third part but also on the first.

Answering RQ2 was preceded by a literature review with focus on (a) how existing models reflect stages within the sensemaking process and (b) how understanding is gained. Based on the outcome of the review, the coding and analysis for RQ2 was guided by the assumptions that:

- Different levels of understanding exist,
- Levels have a hierarchical structure, and
- These levels are manifested in abilities to do something.

4.7.2 Interview coding, category and process diagram development

This section describes the interview coding process and the development of categories for sensemaking challenges, context, activities, cues, and cue types. The process diagram, coding and category development was a parallel process. Coding and diagram development depended on and informed each other. The development was an emergent process with six main phases as shown in Figure 4-3. The phases are described in the following.

<u>1st phase</u>

The 77 relevant episodes (text passages) from 21 interviews were imported into the software NVivo. Each episode was assigned a case number as identifier. Next, researcher comments were added in the text, indicated by brackets and underlined (i.e. <u>[my own comments]).</u> These comments were used to prepare the coding by structuring the text and highlighting important text sections, e.g. sources of information, activities, gaps, cues. The commented episodes were now coded in NVivo. The coding resulted in a list of conceptual nodes for sensemaking challenges, activities and cues. Annotations were added on each sensemaking episode, noting comments and relationships between nodes. Relationships between nodes were described as: triggers, is strategy for, is input for, creates cue (e.g. activity x "creates cue" y, or cue x "is input for" activity y). Relationships were created in NVivo and relevant text passages coded at these relationships.

Having coded 77 episodes the researcher reviewed the result after the 1st coding process. NVivo provides functionality to create models from nodes and relationships. Based on the initial structuring of the interview data it was possible to develop initial diagrams showing the sensemaking process as a sequence of activities and cues used to address a sensemaking challenge. However, the process diagrams were incomplete. As coding of episodes progressed, new nodes and relationships emerged that had not been considered in already coded episodes. These were not yet reflected in all diagrams. Moreover, sensemaking context had not yet been considered in the coding. It was decided to code this only after the initial diagrams had been developed to understand the process better before coding the context. Thus, a 2nd coding phase was started to address these issues.

2nd phase

The coding of each episode was reviewed and improved. Episodes were now coded using all nodes found during phase 1. The review led to reduction of episodes from 77 to 64 because some episodes did not contain sufficiently comprehensive descriptions. Next, the interviews were scanned for sensemaking context using the 14 identified earlier in the literature review as pre-defined coding categories.
The number of nodes for activities and cues increased to 142 and the number of relationships to 581. Next, the activity and cue nodes were analysed for conceptual similarity and grouped into categories. This resulted in 9 categories for activities with 32 dimensions and 15 categories for cues with 110 dimensions (see Appendix B2 for coding structure).

Based on the second coding phase the process diagrams were reviewed using the up-dated nodes from coding and category development. Nodes for sensemaking context were included in the diagrams. This was followed by a comparison of interview text and diagram for each episode to determine whether a sensemaking context change could be found within the process. The final step was to review the diagrams again and transform process elements into abstract elements for cue and activity types. During this step it was discovered that there are specific components that are repeatedly found in the process. These are "cue creation" and "cue use" for activities as well as "indirect" and "direct cues" for cue types.

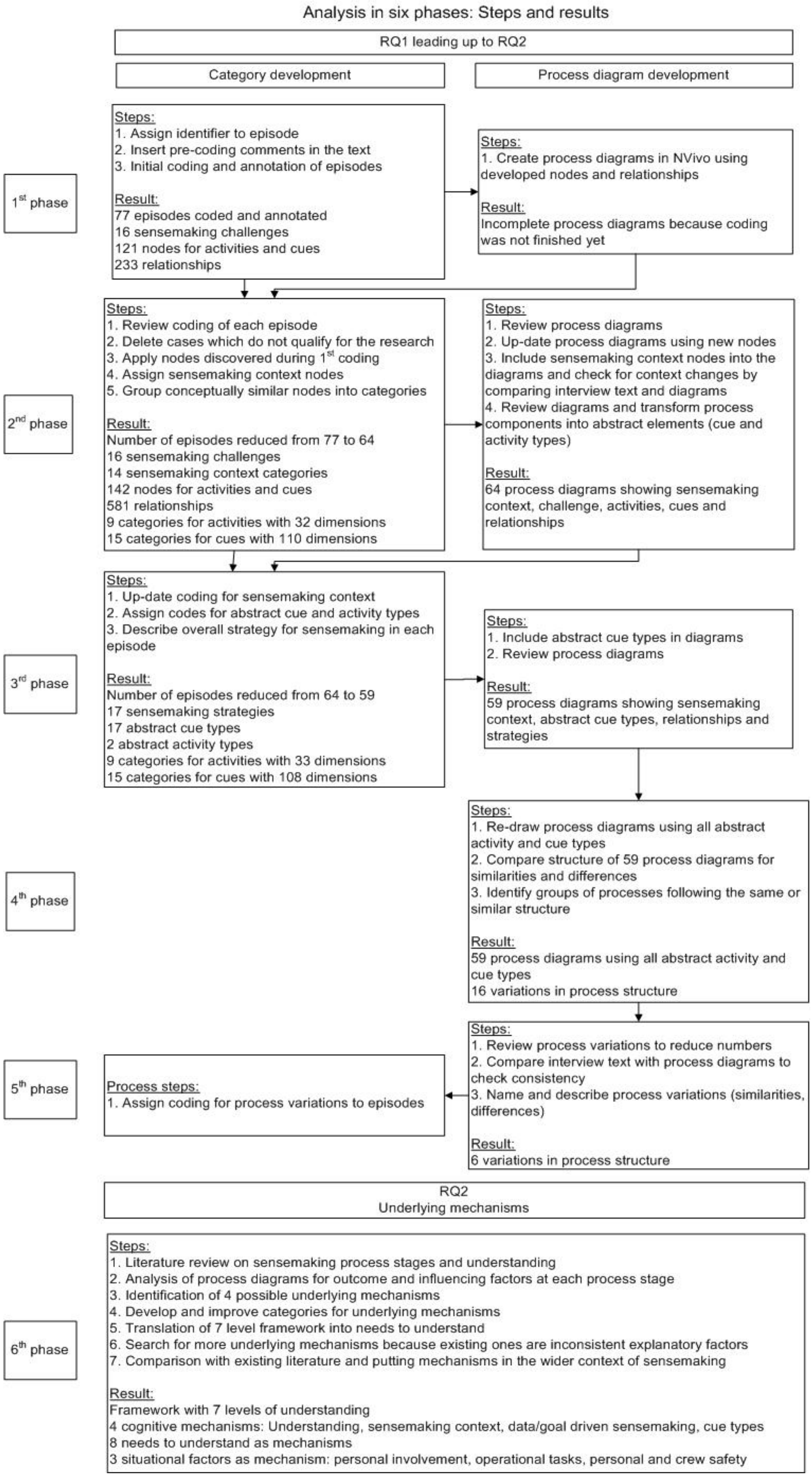


Figure 4-3 - Phases of coding, category and process diagram development

The result of phase 2 process diagram development were 64 process diagrams showing sensemaking context, challenge, activities, cues and relationships (see example in phase 2 diagram in Figure 4-4).

3rd phase

The identification of sensemaking context changes within a process and the development of abstract activity and cue types required up-dating of codes for each episode. Once this was finished, the episodes were reviewed and, where possible, a strategy that could summarise the sensemaking described. The episode review led again to the elimination of episodes from the sample. The result of this phase was the reduction of episode number from 64 to 59, 17 abstract cue and 2 activity types, 17 sensemaking strategies, 9 categories for activities with 33 dimensions and 15 categories for cues with 108 dimensions.

The process diagrams were now re-drawn by adding abstract cue types. A review of process diagrams followed to check the up-date. These steps resulted in 59 process diagrams showing sensemaking context, abstract cue types, relationships and strategies (see example in phase 3 diagram in Figure 4-4). The diagrams now included the 17 abstract cue types which describe the specific cues used in the process. However, they still showed the specific categories of activities and cues based on the coding in NVivo instead of the abstract description, i.e. reduction of specific components to “cue creation” and “cue use” activities as well as “indirect” and “direct cues”.

Phase 4 and 5

These phases concerned only process diagram development (see Figure 4-3). The diagrams were converted using all abstract activity and cue types process (see example in phase 4 diagram in Figure 4-4). This showed the structure of the process without the specific activities and cues as shown in previous diagrams. It simplified the following step, which was the comparison of the 59 diagrams for similarities and differences in the process structure. Based on the comparison it was possible to identify groups of processes following the same or similar structure. The result of the 4th phase were 59 process diagrams using all abstract activity and cue types and 16 identified variations in process structure.

The 5th phase began with a review of the process variations to check if they can be clearly differentiated. As many were very similar and showed only slight variations, they were grouped to reduce the overall number from 16 to 6. Process diagrams were repeatedly checked against the interview text to ensure correctness and consistency of diagrams. The reduction of process variations to 6 made it possible to clearly describe their differences.

Tables were developed for episodes to clearly show the transition and link between the original interview data, the identified abstract process elements and the sensemaking process diagram. An example is shown in Table 4-5. These tables are used in the findings chapter.

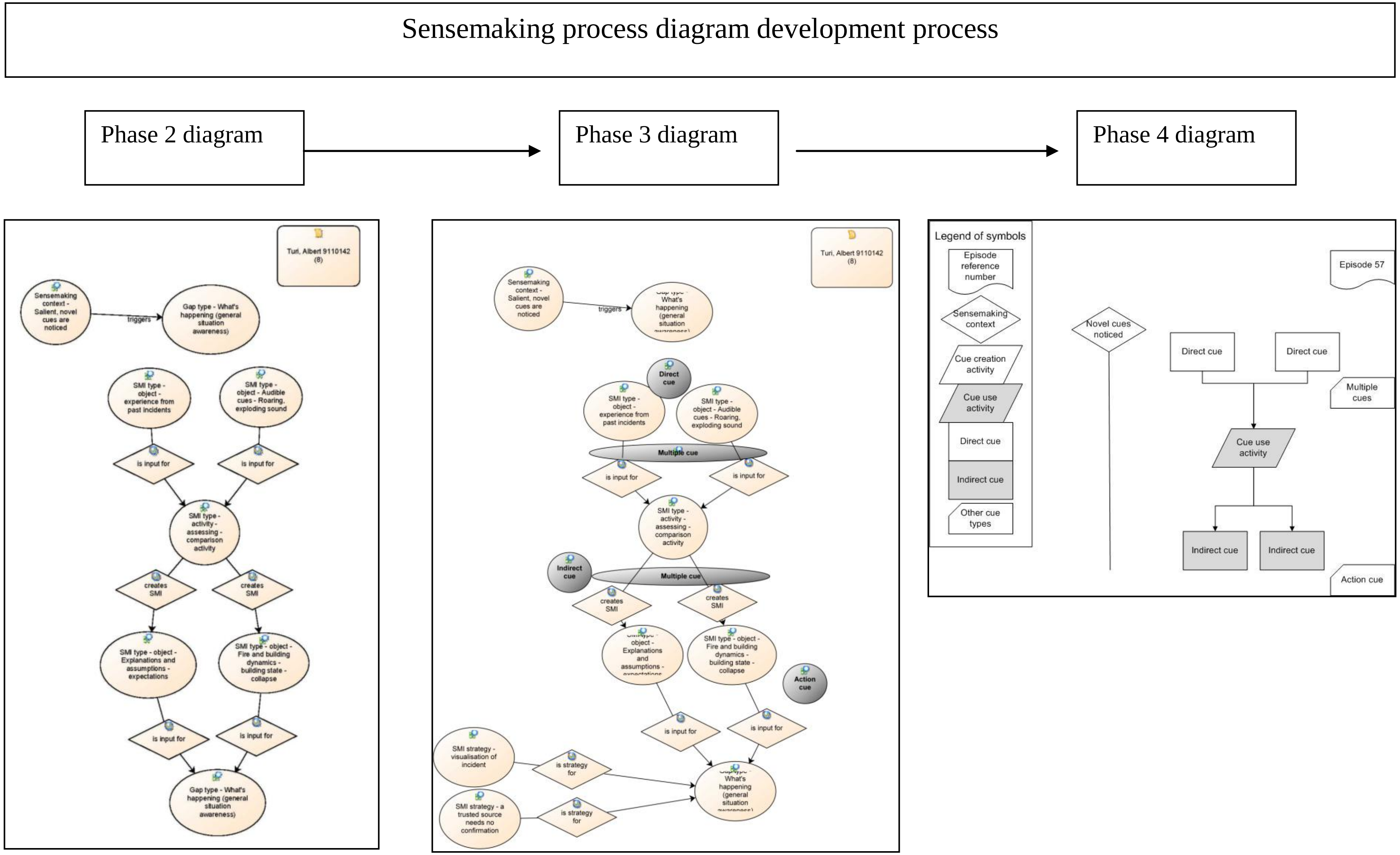


Figure 4-4 - Examples of sensemaking process diagrams phase 1-3 of diagram develpment process

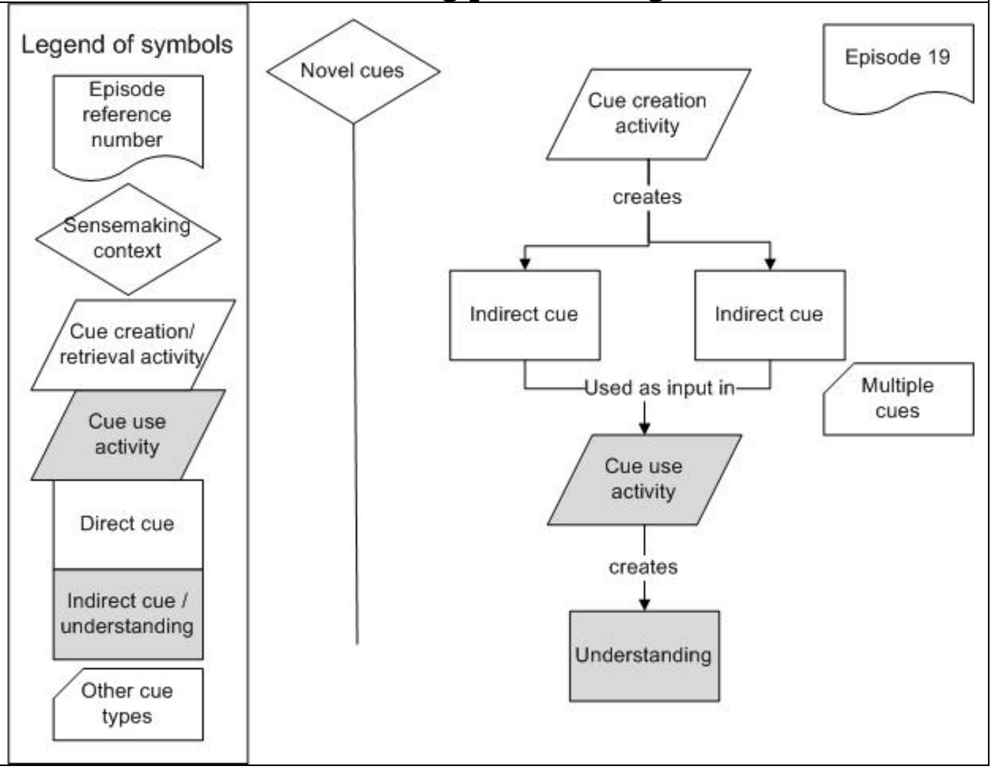
Interview data - Episode 19	Process elements	Sensemaking process diagram
I was watching the fire, watching the people jump and **hearing a noise**	Sensemaking context – novel cue	
and **looking up and seeing** -- it actually looked --	Cue creation activity	
the **lowest floor of fire in the south tower** actually looked like someone had planted explosives around it because the whole bottom I could see -- I could see two sides of it and the other side -- it just looked like that **floor blew out**. I looked up and you could actually see everything blew out on the one floor.	Indirect cue – damage location Indirect cue – damage type	
I **thought**	Cue use activity	
geez, this looks **like an explosion** up there	Understanding	

Table 4-5 - From interview data to process diagram - The simple sensemaking process - example 1

6th phase

This phase relates to answering RQ2, i.e. the possible underlying mechanisms for the process structure.
A literature review (see chapter 3 part 2) with focus on (a) how existing models reflect stages within the sensemaking process and (b) how understanding is gained was carried out at this stage.
However, it was not possible to identify any literature on sensemaking that describes how understanding evolves or through what stages it might evolve. Thus, the researcher turned to literature on learning as well as more philosophical literature on development of understanding and meaning. Here it was found that some authors refer to different types and levels of understanding. Previous analysis and literature review led to the suspicion that gained level of understanding, sensemaking context and data/goal driven sensemaking could be influence factors that explain stages in the sensemaking process.
It was assumed that each process stage comprised the description of the attempt to understand a specific event as well as the outcome of the attempt. This way it would be possible to describe what an individual understood at a specific stage of the sensemaking process. Several questions guided the analysis of each process stage in the process diagrams:

1. What kind of understanding was gained at each process stage?
2. What are the properties of this understanding?
3. What activities were involved in gaining this understanding?
4. What abilities are manifestations of this understanding?
5. Is the stage data or goal driven?
6. How does sensemaking context change at each stage?

In the first phase of the analysis the process diagrams and the interview text were scanned to identify how the outcome of a sensemaking process could be described, i.e. what was understood. This constituted an initial answer to question 1, i.e. what kind of understanding was gained at each process stages. The different types were named and in subsequent iterations of analysis refined. This stage included levels like: speculating what might be, understanding facts and understanding consequences.

The analysis was then repeated to describe each level in more detail, describe properties of each level, the activities used to arrive at this level and the abilities reflected in the gained understanding. A detailed table showing answers to the first four above described questions with references to the relevant episodes was created. Entry levels and exit levels were noted for each episode, showing how understanding evolved. The analysis revealed that people move across levels and build on previous insights to understand different aspects of a situation. The hierarchy included five levels at this stage. A final analysis cycle led to the addition of two more levels in the finalised hierarchy.
The next step was to describe the different movements of understanding across levels of the hierarchy. This was necessary because understanding did not always improve but there were also instances where it dropped to a lower level or showed unsuccessful attempts to move to a higher level.
The final step in the analysis was to trace and test the underlying mechanisms in process diagrams, sorted by process variation (see Appendix D8). This analysis resulted in the

insight that the four mechanisms are not consistent explanatory factors. Therefore, the researcher returned to the raw data and reviewed other possible mechanisms.

4.8 Chapter summary

This chapter detailed the background to the methodology development, the research design, method used and data analysis steps. The following Table 4-6 summarises the position of the dissertation:

Area	Position of dissertation
Philosophical perspective	Constructivist realism
Research strategy	Abductive strategy to establish regularities followed by retroductive strategy to identify underlying mechanism
Theory	Building of tentative theory
Research methodology	Modified constructivist grounded theory
Study context	Response of the New York Fire Department to the events at the World Trade Center on 9/11
Phenomenon	Sensemaking
Unit of analysis	Sensemaking process of individuals
Research questions	RQ1: What process do individuals follow to make sense of events during an emergency? RQ2: Why do stages occur in the sensemaking process? Descriptive for RQ1 and explanatory for RQ2

Table 4-6 - Positioning of the dissertation

5 The 9/11 study: Sensemaking process elements, structure and variations

Chapter 5 presents findings about the sensemaking process. The chapter is split into two parts. To understand the identified process structures and variations in part 2 it is necessary to introduce the process elements first. Thus, part 1 comprises a summary of sensemaking process elements.

Part 1 of the chapter presents

- Sensemaking challenges that the NYFD officers faced (section 5.1.2),
- Elements that were used to reconstruct sensemaking processes, i.e.
  - sensemaking context (section 0),
  - activity and cue types (section 5.1.4).

Part 2 of the chapter presents

- Six sensemaking process variations, including data examples and exceptions (section 5.3.2 - 5.3.7),
- A summary of differences between the variations (section 5.4),
- Insights from the analysis regarding potential underlying mechanisms to prepare further analysis (section 5.4).

5.1 Part 1 – Sensemaking process elements

5.1.1 Overview of identified categories for process elements

This section comprises a description of the categories developed and used to create process diagrams. The following Table 5-1 provides an overview of categories which are described in detail in the indicated sections of the chapter.

Categories for sensemaking challenges, context, activities, cues and relationships						
Sensemaking challenges (section 5.1.2)	**Sensemaking context (section 0)**	**Sensemaking activities (section 5.1.4.2)**	**Activity types (section 5.1.4.2)**	**Sensemaking cues (section 0)**	**Cue types (section 0)**	**Relationships**
Command structure	Absence of expected events	Assessing	Cue creation	Absence of problem	Based on use in activities (section 0) Indirect cue Direct cue	creates cue
Disbelief	Ambiguity	Create confirmatory cue	Cue use	Audible cues		is input for
How to communicate with crew	Complexity	Deliberating	Cue retrieval	Command and control	**<u>Descriptive function (section 0)</u>** Action cue Alternative cue Back-up cue Complimentary cue Confirmatory cue Context changing cue Cue chain Cue composite Information source cue Mental vehicle Multiple cue Non-definitive cue Single cue Unsatisfactory cue Up-dated cue	is strategy for
Information quality	Confusion	Following others		Experience		triggers
Location of resources	Effect uncertainty	Information collection		Explanations and assumptions		
On-site approach, directions	Information load high	Mental projection		Fire and building dynamics		
Orientation	Information load low	Sensegiving		Knowledge		
Problem solving, unknown options	Information quality	Trying out options		Options		
Resource requirements	Novel cues noticed	Using senses		Procedures		
Understanding command post location	Performance uncertainty			Resources		
Understanding the incident	Plausibility			Safety and hazard		
Unknown incident scale	Response uncertainty			Situation dynamics		
Unknown location (of hazard, fire, victim...)	State uncertainty			Sources of information		
Unknown risk	Surprise			Surrounding area		
What's happening	Turbulence			Visual cues		
	Unexpected events					

Table 5-1 - Categories for sensemaking challenges, context, activities, cues and relationships

5.1.2 Sensemaking challenges

The researcher assigned a label to each episode that describes what an individual needed or tried to make sense of. Thus, the following categories are descriptors for the overall theme of episodes.

Sensemaking challenge categories:

1. What's happening
2. Unknown risk
3. Understanding the incident
4. Understanding command post location
5. Disbelief
6. Orientation
7. Information quality
8. Unknown incident scale
9. Location of resources
10. Unknown location (of hazard, fire etc.)
11. Command structure
12. Resource requirements
13. On-site approach, directions
14. How to communicate with crew

Appendix C1 comprises a detailed description of challenges, the wide variety of situations and tasks covered, and frequencies in the data. 14 different challenges were identified. These occurred 74 times in 59 episodes. That means that one episode can comprise more than one challenge. This is the case when one challenge is overcome but immediately triggers a new one. Alternatively, one challenge might consist of several smaller ones. This is described in detail in the later part of this chapter on sensemaking process variations. The first 6 of the above shown 14 challenges account for almost 80% of all occurrences.
In these 6 challenges a specific pattern of occurrence was identified. The episodes were matched against the timeline of events between 08:46am (time of the first plane impact) and 11:28am (when command was re-established after the 2nd tower collapse). Assigning time, location and challenges to the episodes allowed for analysis of patterns, i.e. whether specific challenges occur during a specific period of time, event or at a specific location. The patterns that were identified are shown in Appendix C2. This shows that three challenges (what’s happening, unknown risk and orientation) occurred mostly around the time of towers collapsing. Two challenges (understanding the incident and disbelief) occurred during the beginning stage of the incident. Understanding command post location occurred during the early stage of the incident after the arrival of commanding officers on scene.

About 50% of the episodes were judged to be typical work for fire crews, e.g. initial assessment of the situation after arrival on scene, dealing with information quality, understanding risk for operational safety. The researcher believes that the other 50% of episodes were situations that would be less common but not entirely unusual for the individual commander. These situations had either survival implications, e.g.

understanding the tower collapse and its effects, or were very rare because of the large scale event, e.g. keeping track of hundreds of deployed men.

Although the situations seem to be very diverse, they have several commonalities that make it important to use all episodes for analysis. First, no matter of the context, all of these situations constituted sensemaking challenges and individuals engaged in a sensemaking process. Second, the role of the commander is manifold with great task diversity as demonstrated in the 14 different sensemaking challenges shown above. The commander will have to deal with whatever the situation is, no matter if it is a typical or less common. Thus, keeping the variety of challenges and the more common as well as less common situations was necessary to reflect the reality of command in the dataset. Third, commanders frequently deal with dangerous situations and have to take decisions that can have survival implications for their crew and members of the public. Even in dangerous situations that are completely out of the ordinary for laypeople, the fire commander is still acting as commander.

The seemingly diverse episodes were required to build theory that fits the reality of the command task. The primary role of those acting in the chosen episodes is that of commander as well as individual who needs to make sense.

5.1.3 Sensemaking context categories

The sensemaking context categories that were used in the coding process were already explained in the methodology chapter. The following categories were used and found in the processes (see).

Sensemaking context categories in 9/11 study			
Sensemaking context categories	**Total (=109)**	**%**	**Cumulative %**
Salient, novel cues are noticed	32	29.36	29.36
Uncertainty - Response uncertainty	15	13.76	43.12
Uncertainty - Effect uncertainty	13	11.93	55.05
Uncertainty - State uncertainty	13	11.93	66.97
Information load low	10	9.17	76.15
Ambiguity	6	5.50	81.65
Plausibility	6	5.50	87.16
Information quality low	3	2.75	89.91
Uncertainty - Performance uncertainty	3	2.75	92.66
Unexpected event	3	2.75	95.41
Turbulence	2	1.83	97.25
Expected event missing, surprise	2	1.83	99.08
Complexity	1	0.92	100

Table 5-2 - Sensemaking context categories in 9/11 study

As shown in the total number of cases coded was 109 and 6 of 13 categories account for more than 80% (cumulative %) of all occurrences. Analysis of the 59 episodes showed that each one might have more than one sensemaking context. This explains why the total number of cases coded is 109 instead of 59.

Only 22 episodes had one sensemaking context, whereas 28 episodes had 2, 6 episodes had 3, 2 episodes had 4 and 1 episode had 5 contexts. This means that 80% of episodes (87 episodes) comprised a minimum of two sensemaking contexts.

5.1.4 Sensemaking activities and cues

This section introduces an analogy that aims to explain different activity and cue types that are used in the sensemaking process diagrams in an easy way. A distinction will be made between three activity types (create, retrieve and use cues) and two cue types (direct and indirect).

5.1.4.1 An analogy for sensemaking

The analogy for sensemaking will be baking a cake. Here, the sensemaking process equals the cake baking process, sensemaking activities equal baking activities, sensemaking cues equal ingredients for the cake, and the outcome of sensemaking is understanding which equals the finished cake. To bake a cake (make sense) I need a number of ingredients (cues). I might have bought some ingredients (cues) earlier and stored in a cupboard (memory) at home. These are directly available ingredients (direct cues), waiting to be retrieved (retrieved) and used. If I do not have directly available ingredients (direct cues) or the wrong ones, then I need to engage in a shopping activity (cue creation activity) to get new ones (indirect cues). These are only available after shopping (indirectly). Once I have the ingredients (cues), by taking them from the cupboard (cue retrieval activity) and/or by buying them from the shop (cue creation activity), I can use them (cue use activity) to bake the cake (make sense). However, there is no guarantee that the baking process (sensemaking process) is successful and results in the desired cake (understanding).
In summary, buying ingredients from the shop and/or taking them from the cupboard at home (cue creation/retrieval activities) provide indirectly and directly available ingredients (indirect/direct cues) that are used in a baking activity (cue use activity) to create a cake (understanding).

5.1.4.2 Three activity types

The coding of interview data resulted in the development of nine categories with 31 dimensions for sensemaking activities (see coding structure in Appendix B). The specific activities that were found in the interview data are assigned to three activity types: 1. create new cues, 2. use cues and 3. retrieve existing cues.

Coding categories for activities to create cues comprised: information collection and using senses.
Coding categories for activities to use cues comprised: deliberating, assessing, trial and error, mental projection.

A detailed table including the dimensions of activity categories can be found in Appendix C3.

5.1.4.3 Two cue types

The coding of interview data resulted in the development of 11 categories with 74 dimensions for sensemaking cues (see coding structure in Appendix B). The specific cues that were found in the interview data are assigned to two cue types: 1. direct and 2. indirect cues.

Coding categories for direct cues comprised: knowledge (fire domain specific, command and control, procedural, local), experience, sources of information, audible cues.
Coding categories for indirect cues comprised: audible cues, command and control, explanations and assumptions, building state, smoke and flames, knowledge objects, local knowledge, options, resources (equipment and manpower, people condition), safety and hazard, situation dynamics, sources of information, surrounding area.

A detailed table including dimensions of cue categories can be found in Appendix C3.

5.1.4.4 Descriptive cue types

Phase 2 of the process diagram development included a step to identify abstract descriptors for the cues used in the sensemaking process diagrams. This had the purpose to study the process structure independently of the detailed activity and cue categories.

15 descriptive cue types were identified (see Appendix C4 for details). However, only five became relevant for the remainder of the study. Amongst these are the direct and indirect cues that were already described above. Three more became especially relevant for the process variations (part 2 of this chapter) and underlying mechanisms (chapter 6):
Non-definitive cue: A cue that is not confirmed, of undefined quality, vague or only an initial insight that requires improvement is non-definitive.
Unsatisfactory cue: Insights can be unsatisfactory cues when they represent an undesirable outcome, e.g. of a risk or option assessment. Implausible explanations and insufficient, unconfirmed information are also unsatisfactory.
Action cues: These are insights gained during the sensemaking process which trigger an action. The action is based on the insight.

5.2 Part 1 - Summary

Part 1 focused on the elements of the sensemaking process. The categories for these elements, resulting from the interview coding and analysis of sensemaking processes were presented: 14 challenges, with 6 of them showing a specific pattern of occurrence. 13 sensemaking contexts, 3 activity types, 2 cue types and 3 descriptive cue types were presented. Part 2 presents the process diagrams that were created, using the elements described above.

5.3 Part 2 – Sensemaking process variations

Part 2 of this chapter presents the specific process structures that were found in the data.

5.3.1 Overview of process variations

For each sensemaking episode, the interview data was converted into process diagrams. Several episodes comprised more than one model because sensemaking was not a continuous process but took place at different locations or was interrupted and later continued. This resulted in a total of 91 diagrams from 59 episodes. The 91 diagrams were compared for similarities and differences. Six process variations were discovered. Table 5-3 provides an overview of the variations, frequencies and a brief summary of their structure and differences.

The emergent, simple and multiple stage models account for more than 80% of all observations. Table 5-3 identifies the remaining two models as meta-models, meaning they consist of any and sometimes several of the other models.

The structure to present the variations is as follows: The process variation is briefly summarised and its structure illustrated with a diagram. Then examples from data are given and a table is shown that links the interview data to the abstract elements of the process diagram. Finally the abstract diagram for the specific episode are shown.

Process model	**No. of cases (%)**	**Model structure**	**Differences between the models**
Emergent	33 (36.26%)	Create / retrieve cues – cue use activity - limited understanding – loop(s)* – improved understanding	Limited insight from first part of the process, sensemaking context change possible, 1 or multiple loops* follow to overcome limitation, this potentially improves insight (can be successful but does not have to be).
Simple	22 (24.18%)	Create / retrieve cues – cue use activity - understanding	Short episode, no context change occurs, no complications, no additional data collection, no multiple explanations, action based on the insight, understanding is satisfactory. Either data or goal driven.
Multiple stage	22 (24.18%)	1st stage: create / retrieve cues – cue use activity - understanding; 2nd stage: create / retrieve cues – cue use activity - understanding;	Stage 1 creates an insight, insight is not limited as in the emergent model, new purpose of 2nd stage, taking stage 1 understanding further (can be another aspect of the same situation), usually sensemaking context changes between stage 1 and 2, potential loops* at any stage.
Gap triggers gap **	6 (6.55%)	Emergent, simple, multiple stage or multiple input model	Closing one gap immediately triggers a new one.
Multiple input generation	5 (5.49%)	Create / retrieve cues (aspect 1) – create / retrieve cues (aspect 2) – cue use activity - understanding	Multiple input required from multiple sources, many aspects of a situation need to be considered to fill one gap.
Multiple gap **	3 (3.30%)	Emergent, simple, multiple stage or multiple input model	Multiple input required from multiple sources, many aspects of a situation need to be considered to fill different gaps, one gap has many sub-gaps.
Total	91 (100%)	*Loop = data collection / clarification / confirmation / testing / projection; **Meta-model	

Table 5-3 - Six sensemaking process variations, their frequency, structure and differentiating factors

5.3.2 Simple sensemaking process

Analysis of interviews showed that sensemaking can be a straightforward process without complications. In this case the episode starts with a sensemaking challenge and sensemaking context. The simple sensemaking model (see Figure 5-1) was identified 22 times in interviews and consists of activities to generate cues and using cues. Cues created in the first part of the process might be re-used at a later stage, this time available through direct retrieval as they already exist. Once cues are available they need to be processed further. The cues are used in deliberation, assessment and mental projection activities to create understanding.

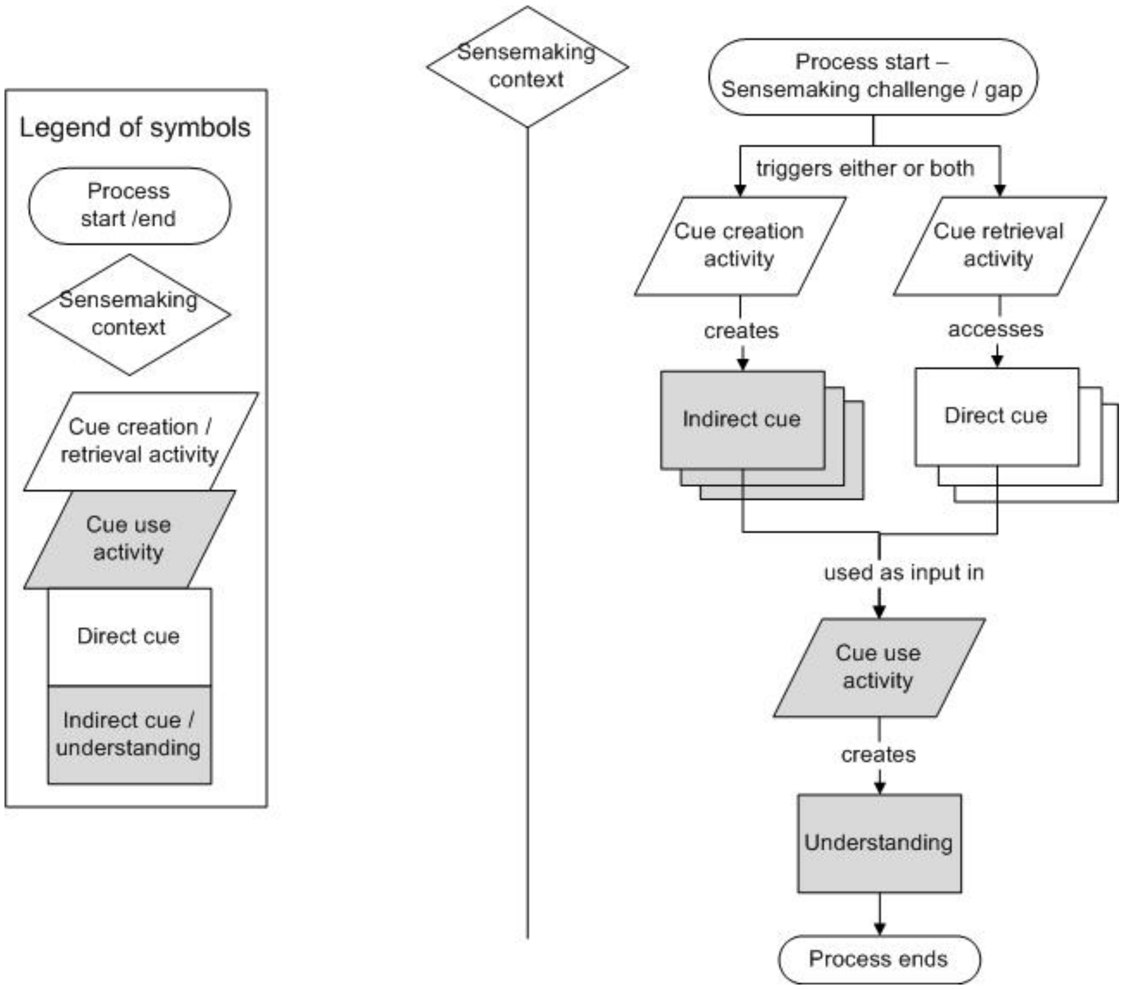


Figure 5-1 - Simple sensemaking process

There is only one cue creating activity in the model. However, the number of cues created varied between one and four, e.g. an observation activity creates the cues damage extent, damage location, smoke and flame location and scale. Direct inputs are not restricted to just one but can be experience as well as knowledge.

5.3.2.1 Data examples

The following two examples in Table 4-5 and Table 5-5 illustrate how the process diagram was derived from the interview data. The process elements as described in section 5.1 were assigned to the relevant text passages. Using the abstract process elements, a diagram was created for each episode.

Example 1 in Table 4-5 shows how a novel cue (i.e. noise) focused attention and triggered the sensemaking process. A cue creation activity follows to see where the noise came from and what it is about, resulting in the creation of two indirect cues, i.e. damage type and location. These cues are used to create the insight that an explosion took place at the upper floors of the building. Thus, the sequence of process elements is: sensemaking context – cue creation activity – indirect cues obtained – cue use activity – understanding.

Example 2 in Table 5-5 shows that direct cues are used next to indirect cues. After a tower collapse two men are engulfed by the dust cloud that rushed through the streets. The effect of being in that cloud is not clear and, thus, the sensemaking context is effect uncertainty. The visibility in the dust cloud is limited, thus, listening is used as cue creation activity to determine if there is any debris falling and how close it is falling. These indirect cues are used together with two direct cues in a risk assessment, i.e. experience of having been through the same incident just before and keeping a safety distance. The outcome of the risk assessment is that the current location is safe enough to stay there for the moment. Thus, the sequence of process elements is: sensemaking context – cue creation activity – indirect cues obtained – retrieve direct cues - cue use activity – understanding.

One reason why sensemaking can be a straightforward process could be the re-use of previous experiences. These are used as direct cues as the following example illustrates.

> Example from episode 57: *"I heard this enormous roar. It was the same roar I heard when the south tower collapsed and I knew that this was collapsing. I didn't even look at it this time. I turned around and I started running."*

The sensemaking context is the perception of a "novel cue" (roaring sound). The interviewee then tries to understand what this cue means. Retrieval of previous tower collapse experience from memory and the perceived sound are both directly available cues and become input for a cue use activity, i.e. comparison of the two and inference of their meaning. The output of this activity is the insight that the 2nd tower is collapsing as well. He acts immediately, without seeking confirmation. Thus, the sensemaking process follows this structure: retrieve cues – use direct cues in sensemaking activity – understanding. Whether his understanding is right or wrong does not matter to him because his explanation seems to be plausible enough to him to act immediately.

In episode 44 a chief describes how he notices new columns in the World Trade Center, which he assumes were built for additional structural safety of the building after the bomb attack in 1993. This observation becomes relevant at a later stage when he is looking for the best option to hide during the tower collapse.

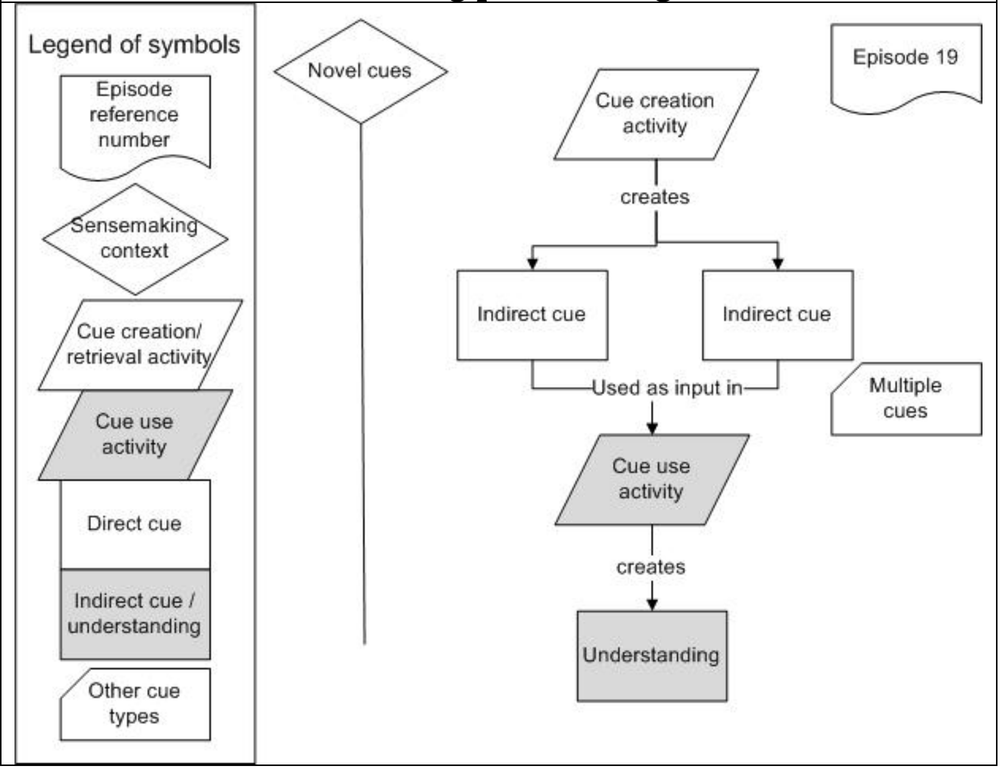
Interview data - Episode 19	Process elements	Sensemaking process diagram
I was watching the fire, watching the people jump and **hearing a noise**	Sensemaking context – novel cue	
and **looking up and seeing** -- it actually looked --	Cue creation activity	
the **lowest floor of fire in the south tower** actually looked like someone had planted explosives around it because the whole bottom I could see -- I could see two sides of it and the other side -- it just looked like that **floor blew out**. I looked up and you could actually see everything blew out on the one floor.	Indirect cue – damage location Indirect cue – damage type	
I **thought**	Cue use activity	
geez, this looks **like an explosion** up there	Understanding	

Table 5-4 - From interview data to process diagram - The simple sensemaking process - example 1

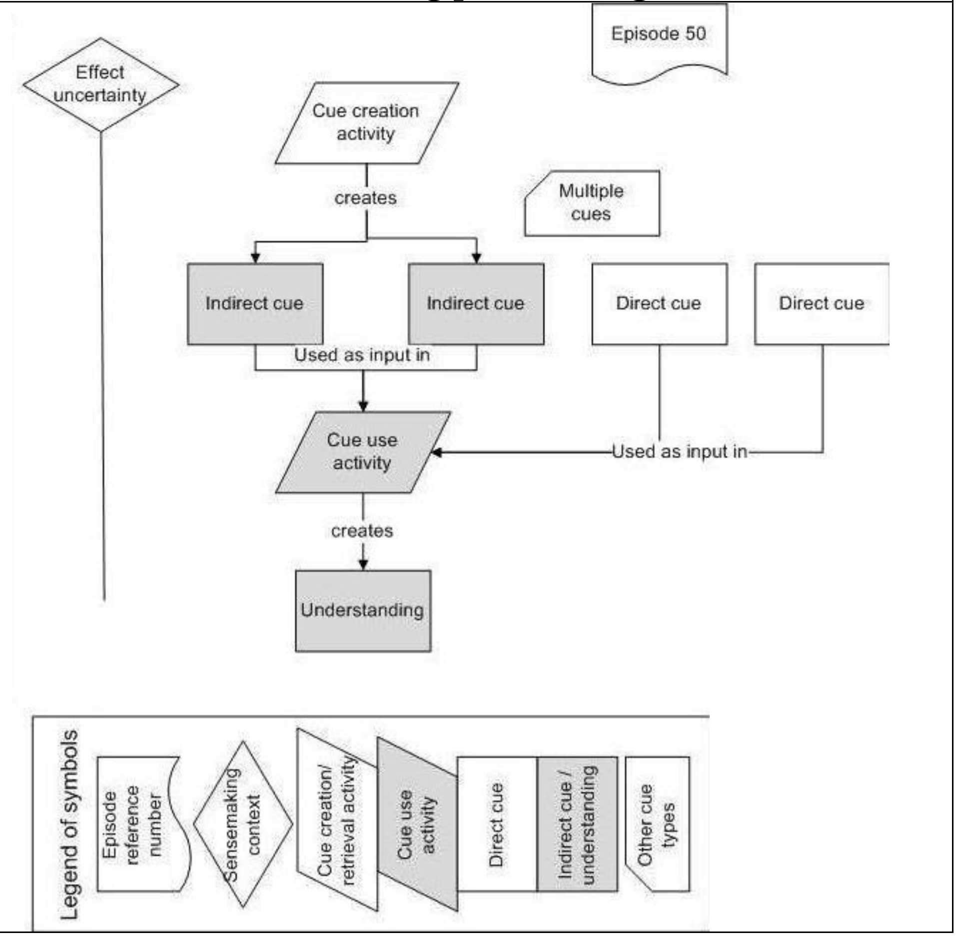
Interview data - Episode 50	Process elements	Sensemaking process diagram
And there was a young firefighter next to me who said **we're going to die here, we're going to die, I can't breathe**, and I remember saying to him	Sensemaking context – effect uncertainty	
I just went through this 20 minutes ago. You're not going to die. Just calm down. We're going to wait here for ten minutes, whatever it takes, and we'll be fine. We're not dead yet.	Direct cue – experience from previous incident	
I could **hear**	Cue creation activity	
pieces of **metal falling** in **the area**	Indirect cue – falling debris Indirect cue – location, direction Direct cue – safety distance	
but **nothing really close**	Cue use activity – risk assessment	
(nothing) that concerned me.	Understanding – safe zone	

Table 5-5 - From interview data to process diagram - The simple sensemaking process - example 2

5.3.2.2 Special cases and exceptions

Sensemaking is not always successful. In the previous episodes the sensemaking process is straightforward and without complications. However, understanding might not be gained at the end of the process. Episode 14 is an example for such a situation. Here, a FDNY member observes people jumping from a tower. Although he clearly observes what is happening he cannot believe that this is happening and just continues staring. It seems that he cannot create an understanding of how and why people do it.

Another example of an apparently unfinished sensemaking process as well as of a situation where cues become available indirectly is illustrated in episode 15:

> *"I remember glancing to my right, and Joe Mazzarella was at that moment looking up. I suddenly saw his face like a look of complete terror, and he just turned on his heel and took off running. I started running after him."*

Although the interviewee does not describe that a specific understanding is gained, it is assumed that he infers that something is happening that is worth imitating his colleague's behaviour and run away (in this case the first tower started to collapse). The cue becomes available indirectly because his colleague sees what is happening.

5.3.2.3 Summary

Characteristics of the simple process model are (see Table 5-3): Short episode without complications or context change, gained understanding is neither unsatisfactory nor implausible. However, when the process outcome is not satisfactory the process follows a different structure as described in the following sections.

The simple sensemaking process operates in two ways. First, it is a stand-alone model in which case the use of only one sensemaking activity is sufficient to gain new understanding. It is very obvious what the cues mean or it is not difficult to derive meaning. When the outcome is sufficient understanding the process ends and there is no need to go through additional loops of data collection or clarification. Second, the model is a building block for longer sensemaking episodes that follow a different process structure. Through a combination of several simple structures new, more complex process varieties are created. As described in the following sections, simple structure varieties were found as linear sequences, parallel processes and loops in the sensemaking process.

5.3.3 Emergent sensemaking process

Although sensemaking can follow a straightforward process this was not the case in the majority of episodes analysed. Here, understanding emerges as a result of multiple process stages. These stages can be spread over time, take place at different locations and each have one cue use activity. The emergent sensemaking model (see Figure 5-2) was identified 33 times and consists of two parts, i.e. the above introduced simple process followed by at least one loop. The first part of the process results in an initial explanation or assumption. Although understanding is gained, it is limited, e.g. unconfirmed, insufficient or implausible. Thus, a process loop follows to collect data, confirm or refute assumptions, test plausibility or improve explanations. This creates more cues which are then used together with the initial insight to create understanding that is improved, up-dated or corrected. If understanding is still limited, then another loop might be entered. Understanding emerges as a result of multiple process stages.

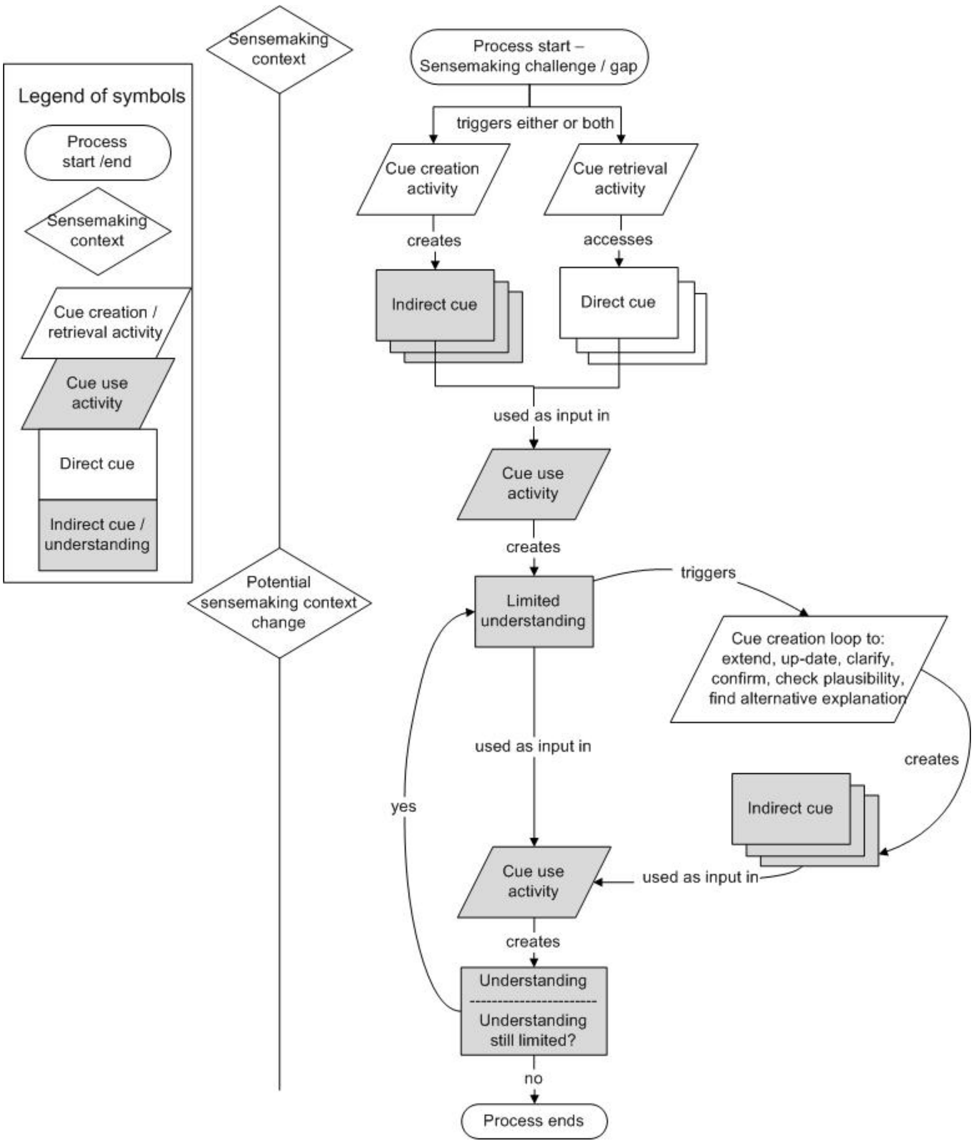


Figure 5-2 - Emergent sensemaking process

Several loop types were identified:

- Extend and improve an initial explanation,
- Up-date or clarify current understanding,
- Confirm or disprove an assumption,
- Check plausibility of initial explanation,
- Find an alternative explanation,
- Physically trying out or mentally simulating a course of action to create feedback whether it is a viable option.

New cues are created in these loops and then compared and integrated with the previous ones to gain improved understanding. If the level of understanding is now sufficient, the gap can be closed.

5.3.3.1 Data examples

The following two examples in Table 5-6 and Table 5-7 illustrate how the process diagram was derived from the interview data.

Example 1 in Table 5-6 shows how information becomes available when it is sent via beeper. It is retrieved directly and used in a thinking activity to create an initial explanation of what happened. However, this initial explanation is described in the diagram as non-definitive cue, i.e. the interviewee cannot be sure that his explanation is the right one. Thus, he enters a data collection loop in which a cue creation activity (information collection) results in multiple pieces of information on the incident provided by a colleague. This is used to up-date his explanation. In the light of the new information the initial explanation needs to be discarded in favour of a better one. The sensemaking process follows the structure of: retrieve cue – obtain direct cue – cue use activity – limited understanding – data collection loop – obtain indirect cues – cue use activity – understanding. The data collection loop consists of a cue creation activity to obtain new cues and the following cue use activity to integrate the initial understanding with the newly obtained cues. Thus, the first part of the process and the loop follow the same structure as the simple process model.

Example 2 in Table 5-7 shows how the sensemaking is triggered by an ambiguous exclamation. Thus, the sensemaking context of the episode is ambiguity because it is not clear what it means. Observation as cue creation activity follows to create multiple indirect cues (damage type and location on the building). These are used in a cue use activity to create an initial explanation of what is going on, i.e. a secondary explosion took place in the tower. However, this is again a non-definitive cue because it was created with only minimal information. Continued observation activity in a data collection loop produces more indirect cues which result in a correction of the initial insight (an explosion). The corrected and up-dated insight is that the building is collapsing. The sensemaking process follows the structure of: create cue – obtain indirect cue – cue use activity – limited understanding – data collection loop – obtain indirect cues – cue use activity – corrected understanding.

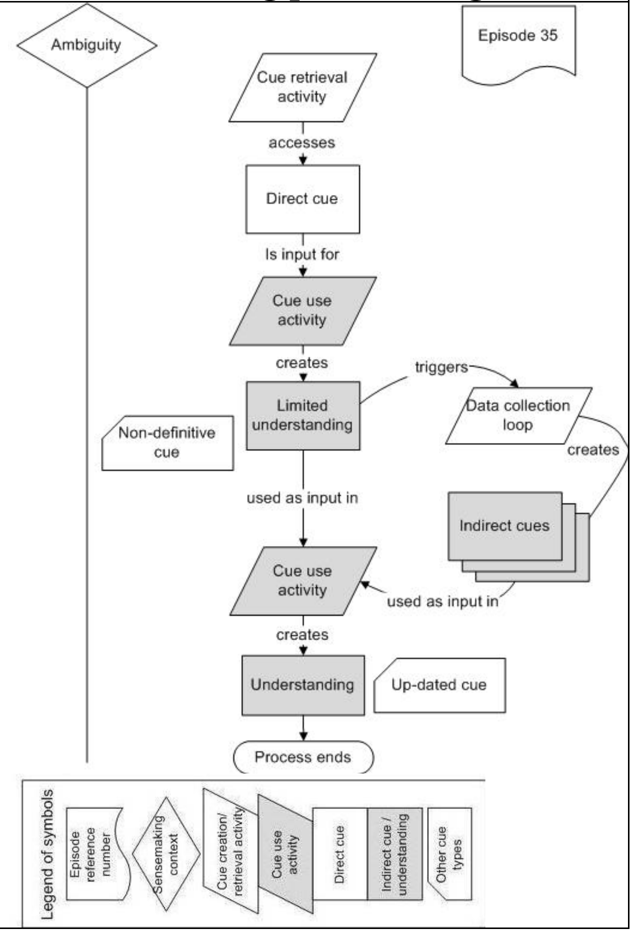
Interview data - Episode 35	Process elements	Sensemaking process diagram
As I was leaving, I remember as I was leaving the high school after voting, my beeper went off, a page for 722-2900, which is up here on the fifth floor, which I assume is Murf. My car was probably 15 feet away and I said I will wait until I get into the car and call him. As I put the key into the car door, that's when I believe the **first page I got was 33 for plane crashing into the World Trade Center**, a third alarm. So I didn't think -- I didn't know what it was	Sensemaking context – ambiguity Direct cue – information source - beeper	
I'm **thinking**	Cue use activity	
maybe a small aircraft.	Limited understanding – initial explanation	
I get into the car, **I call Murf, asked him what's going on.** He said have you heard it, yes. Plane crashed. No, at that point I believe he said looks like it was a **big big crash** and I think he said at that point he also told me that the **second crash** had just taken place. He said **it looks bad**. They were watching it from the windows at Hooper Street.	Cue creation activity – data collection (several indirect cues obtained)	
	Cue use activity (not described here but initial explanation is discarded in favour of better explanation what happened)	
I told him **okay**.	Understanding	

Table 5-6 - From interview data to process diagram - The emergent sensemaking process - example 1

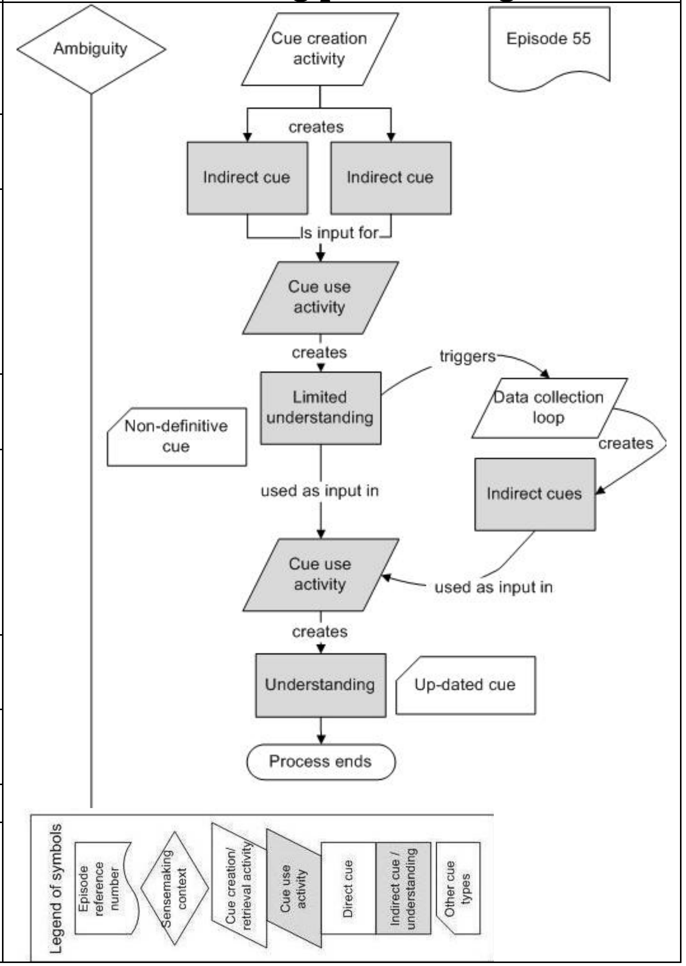
Interview data - Episode 55	Process elements	Sensemaking process diagram
We were not in the garage. Maybe 20 feet from the opening of the garage. The next thing I heard was Pete say **what the fuck is this**?	Sensemaking context – ambiguity	
And as **my eyes traveled up the building, and I was looking** at the south tower,	Cue creation activity	
somewhere **about halfway up**, (my initial reaction was there was a secondary explosion,) and the entire floor area, **a ring right around the building blew out**.	Indirect cue – damage location Indirect cue – damage type	
my initial reaction was [author comment: text passage taken from above]	Cue use activity	
there was a secondary **explosion**, [author comment: text passage taken from above] (I later realized that the building had started to collapse already and this was the air being compressed and that is the floor that let go.)	Limited understanding – initial explanation	
And as my eyes traveled further up the building,	Cue creation activity – data collection	
	Indirect cue not described here	
I **realized** that	Cue use activity	
this **building was collapsing**	Up-dated understanding	

Table 5-7 - From interview data to process diagram - The emergent sensemaking process - example 2

5.3.3.2 Special cases and exceptions

In some instances multiple data collection loops were found. In episode 8 a fire chief does a reconnaissance tour round the towers to see the damage to the buildings from multiple vantage points. Thus, data collection occurs at multiple locations as well as over time. Another example is episode 8 where a FDNY member asks civilians who are evacuating a tower via a stairwell whether they have seen any fires and at which floor. He asks many civilians over time to assemble a picture from multiple pieces of information from many sources.

Sensemaking context changes might occur after an initial explanation is created. Episode 12 is an example for this. A fire chief hears a noise (sensemaking context – novel cue) and his initial explanation is that another plane is flying over Manhattan. He tests this explanation for plausibility (i.e. sensemaking context changes to plausibility) by collecting more cues through observation. He sees that a tower is collapsing which results in discarding the initial explanation.

Attempts to confirm an assumption or initial explanation are not always successful as the example from episode 45 illustrates:

> *“We weren't getting good reports from the police at all. There was one point there was a possibility of a second plane coming in and somebody said something and I turned around to try to confirm that and we couldn't confirm that.“*

The sensemaking context is “low information quality”. New information results in an assumption that another plane might be on its way to the scene. This is followed by a confirmation loop, which is unsuccessful in this case. Thus, the assumption remains unconfirmed.

5.3.3.3 Summary

The emergent model is relevant for situations where the gained understanding has limitations. If understanding is implausible, unsatisfactory or an assumption, then one or multiple sensemaking loop(s) follow to address this limitation through additional data collection, clarification, confirmation and testing.
Characteristics of this model are (see Table 5-3): Limited insight from first process phase, one or multiple loops to overcome this limitation, understanding mostly improved in 2nd process phase, context change might happen between phase 1 and 2. Both phases seem to follow the simple process model structure. The following multiple stage model has also two process stages. However, these are linked in a different way.

5.3.4 Multiple stage sensemaking

The multiple stage model (see Figure 5-3) consists of two process stages. During the first stage separate simple sensemaking processes create one or many new items which each constitute some kind of insight and understanding. In contrast to the emergent model the outcome of the first stage is understanding that is not limited, e.g. unconfirmed. The second stage builds on the already gained understanding and takes it further.

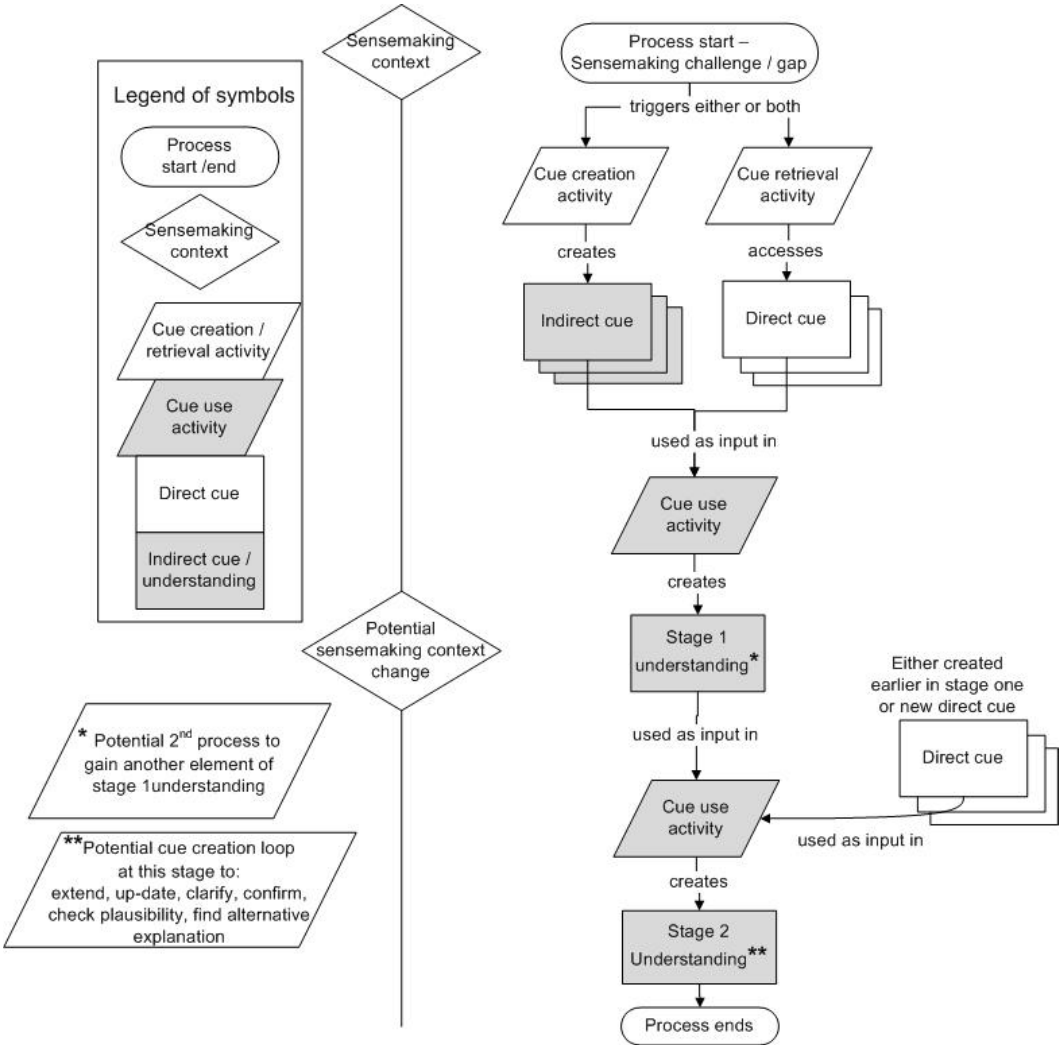


Figure 5-3 - Multiple stage sensemaking process

Additional input at this stage can be generated in a separate cue creation and retrieval activity. This second stage of the process enhances the understanding even further. An example for the first stage of this model is understanding of the current situation, e.g. what is going on. At the second stage this understanding is used to make sense of the consequences, e.g. risk, available options or courses of action. The understanding of stage 1 becomes the input for stage 2. A stage 2 insight depends on stage 1 insight, i.e. consequences cannot be understood before the situation is understood. Moreover, there might be a context change between the first and second stage from response uncertainty to effect uncertainty. Also, it was found that a second separate process might occur at stage 1 to create a second item of stage 1 understanding (indicated by the single asterisk in Figure 5-3), in which case both are used at the 2nd stage. Moreover, additional loops can occur but do not have to (indicated by the two asterisks in Figure 5-3).

5.3.4.1 Data examples

The following two examples in Table 5-8 and Table 5-9 illustrate how the process diagram was derived from the interview data.

Example 1 in Table 5-8 shows how observation as cue creation activity creates three cues (location, scale of smoke and flames as well as fire burning characteristics). These are used to create stage 1 understanding, i.e. the explanation of what is going on is that an explosion is happening. Next, the interviewee describes another insight, i.e. that he and his colleagues are in the collapse zone of the explosion. Although this is not described it is inferred that he uses the previously created cues, his initial understanding as well as knowledge on safety distances in a risk assessment to create the insight at the second stage of the process. This means the outcome of the process is an understanding of the effect that this explosion has for his personal safety. Thus, the sensemaking context of the second process stage is described as effect uncertainty. This means that stage 1 understanding was a context changing cue (from novel cues to effect uncertainty) and stage 2 understanding a non-satisfactory as well as action cue. Not the understanding is non-satisfactory but the situation that the person is in. The insight also triggered the action of running away. The sensemaking process follows the structure of: create cue – obtain indirect cue – cue use activity – stage 1 understanding – retrieve direct cues – cue use activity – stage 2 understanding. Thus, each of the two stages follows the structure of the simple sensemaking process.

Example 2 in Table 5-9 illustrates how initial understanding of the incident scale is used to create understanding about response options. This means that the first stage of the model is about figuring out what is going on and the second stage about understanding if a usual response is applicable. The observation of the tower results in creation of cues on scale and location of the fire and damage. These are used to create an estimation of the incident scale, which constitutes the outcome of the first stage. The structure follows: cue creation (observe) – obtain indirect cues (fire and damage location and scale) – sensemaking activity (create estimation) – stage 1 understanding (estimated incident scale). Stage 1 understanding changes the sensemaking context from novel cue (for which meaning is now established) to response uncertainty, which describes the 2nd process stage where the interviewee thinks about the possible response to an incident of this type and scale. At the second stage of the process he uses the estimation of incident scale together with knowledge about resource requirements and capabilities (retrieve cues) to create (sensemaking activity, i.e. cue comparison) the insight that extinguishing the fire is not an option (understanding). Understanding if a usual response is applicable depends on the estimation of the incident scale. This stage 2 understanding is an unsatisfactory cue because it does not result in finding a suitable response.

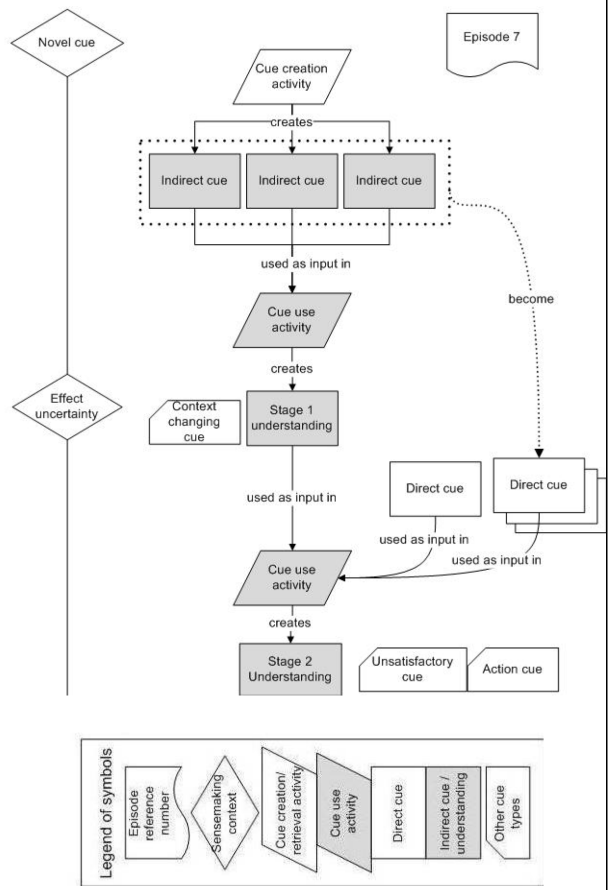
Interview data - Episode 7	Process elements	Sensemaking process diagram
So we just ran as a unit to the overpass again, and we **took a look**	Sensemaking context – Novel cues Cue creation activity	
up, and it was like one -- it was like, holy shit. It was like -- because it was like -- I guess the building was kind of -- I don't remember specifically, but I remember it was, like, we got to get out of here. I think that the building was really **kind of starting to melt**. We were -- like, the melt down was beginning. The collapse hadn't begun, but it was not a fire any more up there. It was like -- it was like that -- like **smoke explosion** **on a tremendous scale** going on up there.	Indirect cue – smoke and flames - location Indirect cue – fire burning characteristics Indirect cue – smoke and flames - scale	
It was like -- it was like that -- like	Cue use activity – comparison	
smoke explosion	Stage 1 Understanding Sensemaking context – effect uncertainty	
Direct cue – smoke and flames - location Direct cue – fire burning characteristics Direct cue – smoke and flames - scale Direct cue – understanding Direct cue – Safety distance	Cue use activity (not described, assumed that it is a risk assessment because he describes an insight next. Assumed that he is using previously created cues, i.e. they are now direct cues.	
I said to the guys -- I said, "**We are in the collapse zone**." I mean, that sounds like a joke, but I said, "We got to -- **we can't stay here**." So we started running up West Street, and I'd say within 50 yards or so the building was collapsing behind us…	Stage 2 understanding	

Table 5-8 - From interview data to process diagram - The multiple stage sensemaking process - example 1

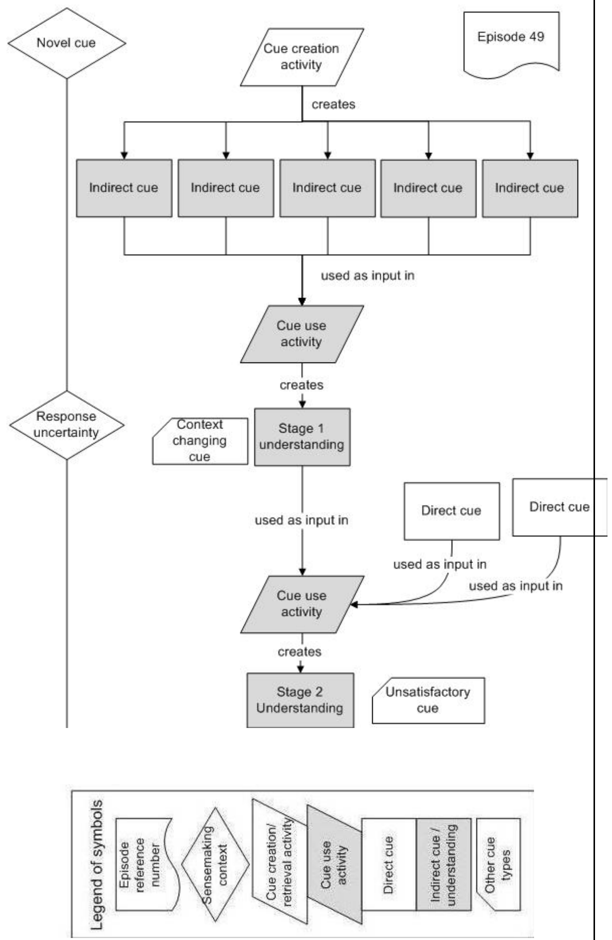
Interview data - Episode 49	**Process elements**	**Sensemaking process diagram**
At some point when I was going over the Brooklyn Bridge, **I could clearly see the tower and I started counting**	Sensemaking context – Novel cues Cue creation activity	
what I thought was **how many floors** were **involved in the fire**, and from that vantage point I thought we had somewhere between **six and eight floors of fire**, **floor areas** that I would consider to be **fully involved in fire** […].	Indirect cue – damage extent Indirect cue – smoke and flames - scale Indirect cue – smoke and flames - location Indirect cue – fire burning characteristics Indirect cue – damage location	
what I thought was [author comment: sentence taken from above]	Cue use activity	
	Stage 1 Understanding – estimation of incident scale Sensemaking context – Response uncertainty	
Then I further stated that we do not have the capability to put that many floors of fire out. I knew right from the start that there was **no way this Fire Department could extinguish six or eight floors of fire fully involved in a high-rise building**. It's just not possible because **we don't have the means to do it**.	Cue retrieval activity – requirements Cue retrieval activity – capabilities	
	Cue use activity – anticipation of problems (comparison of requirements, capabilities and stage 1 understanding)	
Then I further stated that **we do not have the capability to put that many floors of fire out**. [author comment: sentence taken from above]	Stage 2 understanding	

Table 5-9 - From interview data to process diagram - The multiple stage sensemaking process - example 2

However, it rules out what is not possible. In this example, stage 1 result in understanding of approximate incident scale and stage 2 builds on this insight thinking about a possible incident response. The sensemaking process follows the structure of: create cue – obtain indirect cue – cue use activity – stage 1 understanding – retrieve direct cues – cue use activity – stage 2 understanding. Thus, each of the two stages follows the structure of the simple sensemaking process.

5.3.4.2 Special cases and exceptions

As indicated by the asterisks in Figure 5-3 the multiple stage process might vary. Two instances (episode 20 and 48) were found where stage 1 of the multiple stage model has two separate branches, resulting in 2 elements of stage 1 understanding. Both become input for the cue use activity at stage 2.

In episode 20 a chief observes the beginning tower collapse. The first branch of stage one results in the insight that the tower is collapsing, the second branch results in the insight that the debris is spreading a far distance. Both insights represent stage 1 understanding. Building on these two, the fire chief figures out the consequence for himself as he is standing in the street next to the collapsing tower, resulting in the insight that he is not far enough away from the collapsing tower to escape the falling debris.

In episode 48 a FDNY member sought shelter from a tower collapse in a garage, close to its entrance. The dust cloud in the garage makes breathing difficult and he fears to suffocate. Stage 1 of the multiple stage process results in creation of two possible options for directions to go (deeper into the garage where many other people are or outside where conditions are not known and debris might block the exit). At the second stage these two options are integrated through comparison.

5.3.4.3 Summary

The multiple stage model is characterised by two stages where understanding from the first stage becomes input and is built upon in the second stage (see Table 5-3). No limitation as in the emergent model is attached to stage 1 understanding. There might be a context change between the first and second stage, indicating that the second stage is about understanding a new aspect of the same situation.

5.3.5 Multiple input generation process

This process is a variation of the simple sensemaking process and was identified five times in the data. In the simple process only one type of activity is used to generate cues. In contrast, several different activity types are used in this model to generate different types of cues (see Figure 5-4). For example, activities of observation, listening and seeking specific information are used in combination to generate cues that are part of various categories, e.g. surrounding area, resource location, assignments, command structure and hazards.

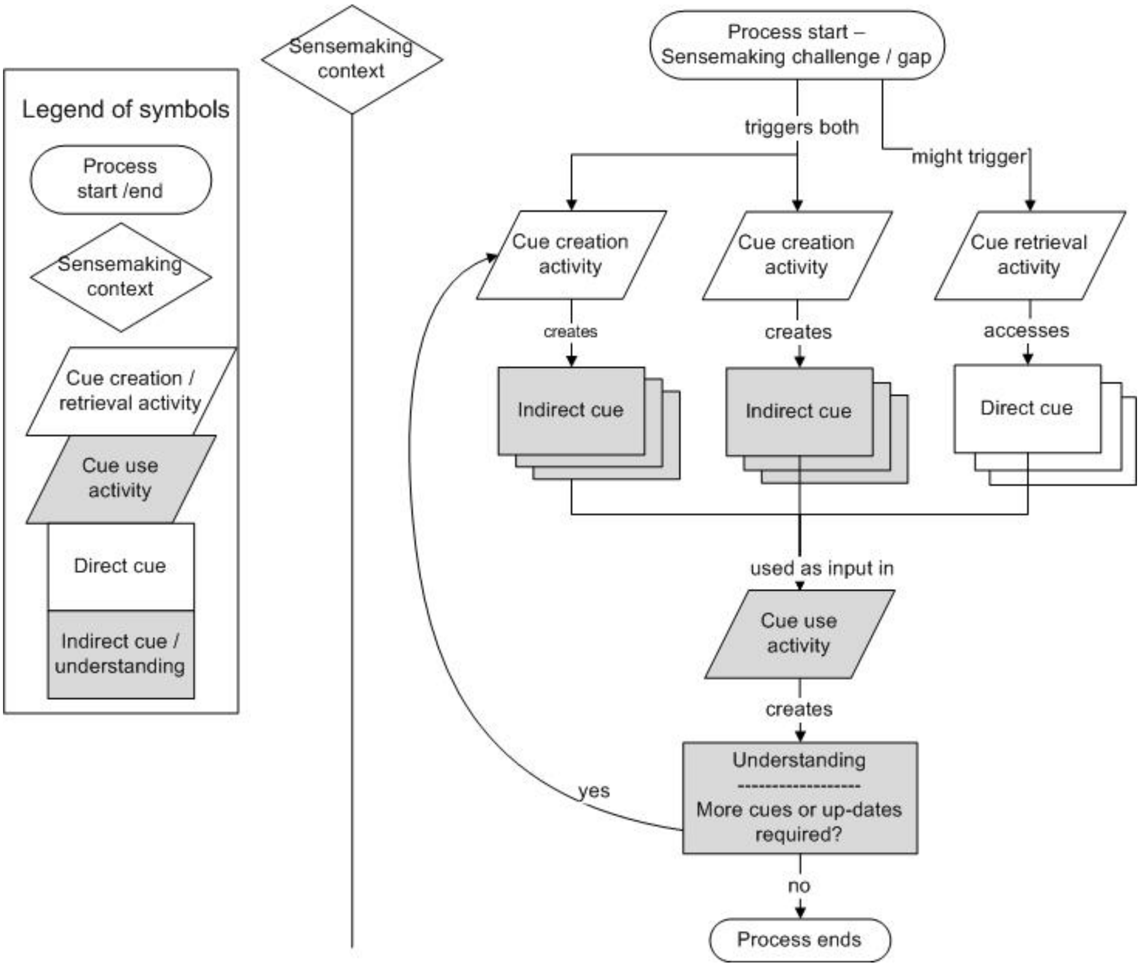


Figure 5-4 - Multiple input generation process

5.3.5.1 Data example

The following example in Table 5-10 illustrates how the process diagram was derived from the interview data.

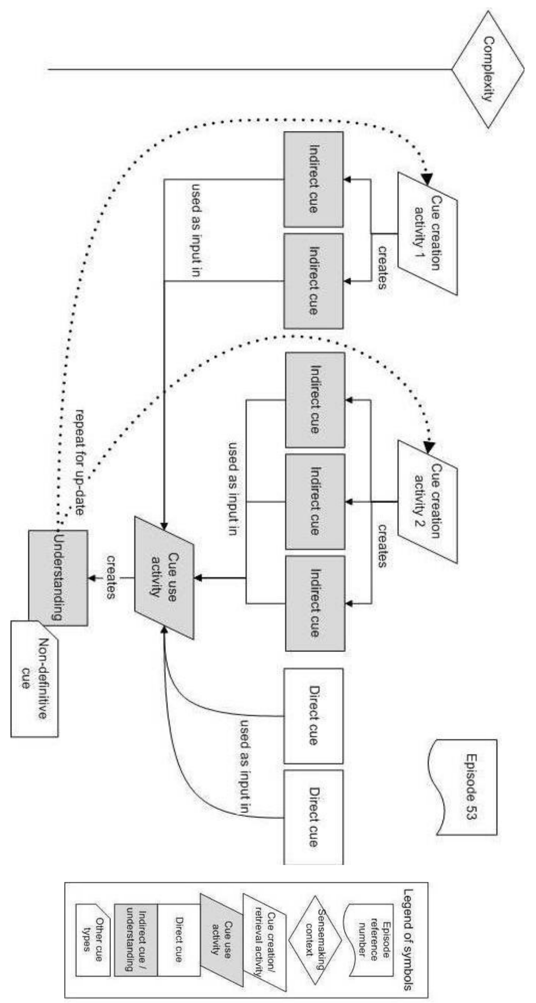
Interview data - Episode 53	Process elements	Sensemaking process diagram
Then we were trying to **establish communications** with both towers trying to **figure out what commanders were in what tower**.	Sensemaking context – Complexity Cue creation activity 1 – information collection Indirect cue – command structure (also the understanding they want to gain) Indirect cue – location of resources	
We were trying to set up the command board to place units, **where we had assigned them** or who **had been previously assigned before we got there**, and the **handie-talkie communications** were very poor at best. […]	Indirect cue – location of resources Indirect cue – assignments Indirect cue – mobilised resources Cue creation activity 2 – information collection	
So we were trying to identify the companies and place them, we were **trying to get units on the proper radio**. We had chosen **different frequencies for different buildings**. We were not very successful contacting all the units or all the commanders. […]	Cue creation activity 2 – information collection Direct cue – means of communication Direct cue – knowledge of frequencies	
And I **started writing this all down on a clipboard**, which I later lost, so unfortunately I don't have that record.	Cue use activity	
[bigger picture of command structure and deployed resources]	understanding	

Table 5-10 - From interview data to process diagram - The multiple input creation process - example

The example in Table 5-10 describes the task at the command post to coordinate arrival and deployment of companies. A command board is used at the incident command post which holds all important information on the current state of the incident, e.g. deployed resources, assignments, commanders in charge. The commander's understanding of current resource location, deployment and requirements depends on input about resource availability, current assignments and degree of completion, reports from deployed companies and the control center. Understanding of the current picture of resource location and deployment depends on many elements. Thus, in order to relate these different elements to each other, they need to be generated first, i.e. the sensemaking activity cannot be started before many different relevant cues exist. The outcome of the sensemaking activity might be only a partial picture and incomplete understanding. In this case the test, if more or different cues are required to improve the understanding, can lead to a return to cue generation activities.

In episode 30 another example for work on the command board can be found. It also follows the multiple input generation process. Episode 40 represents another example for this process. Here, a chief goes on a reconnaissance tour round the towers to build a picture of the incident. He collects multiple pieces of information from multiple sources to assemble and up-date his understanding.

There were no case specialities or exceptions found for the multiple input generation process.

5.3.5.2 Summary

This model is applicable to situations where one needs to assemble a bigger picture from multiple smaller components. Thus, the model is characterised by multiple cue creation/retrieval activities to obtain multiple cues from multiple sources in order to cover different aspects of the situation.

5.3.6 Multiple gap process

The multiple gap process was identified three times in the data and is the first of two meta-models (see Table 5-3). This means that the sensemaking process might follow any of the four previously presented variations. One gap in understanding can require sensemaking of several smaller sub-gaps, i.e. multiple gap sensemaking (see Figure 5-5). In order to see the big picture it is necessary to understand different components and their relationship.

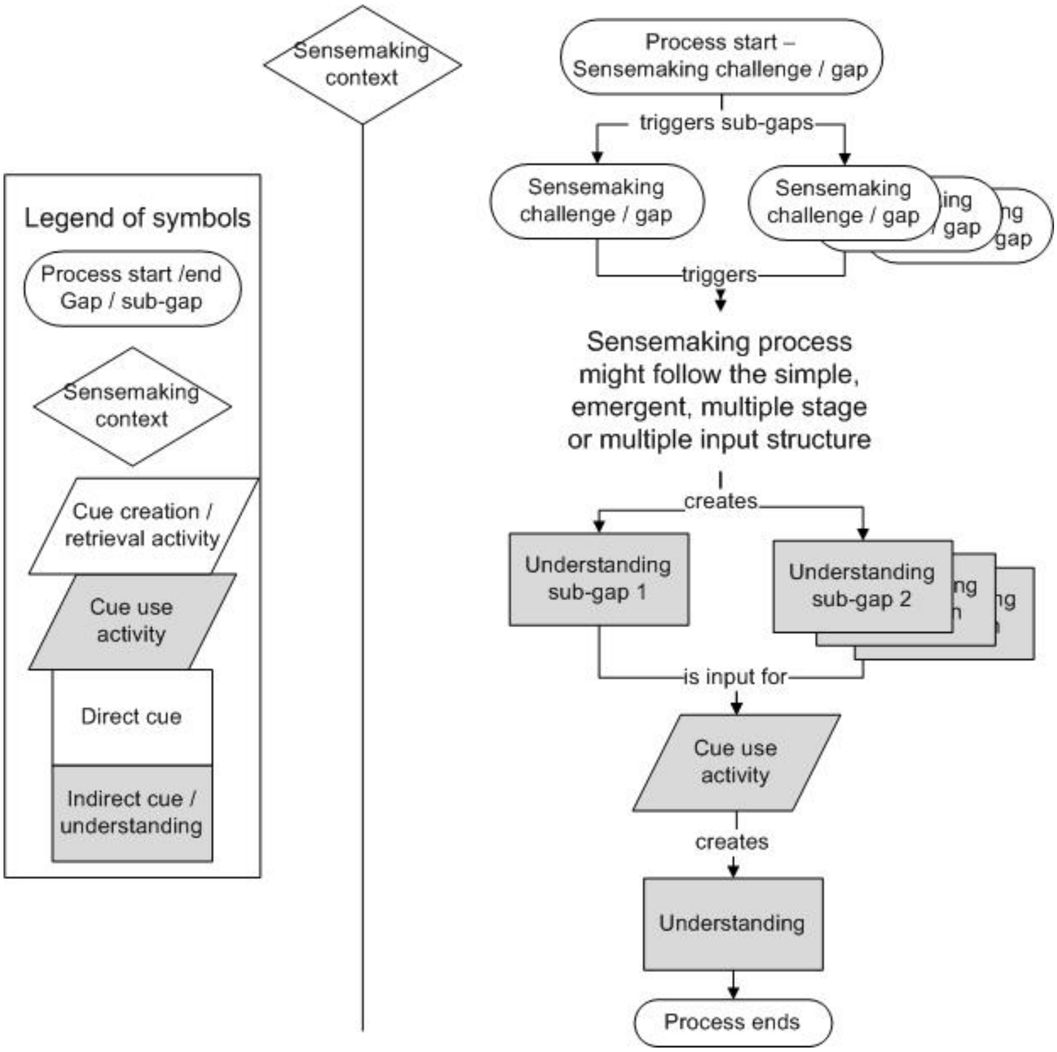


Figure 5-5 - Multiple gap process

The multiple gap process was observed at the beginning of an incident when there is not much known yet about the situation. Many elements contribute to the understanding of the incident, e.g. resources, risk, scale, hazards. For example, in one episode a fire chief described how he did a reconnaissance tour around the two towers to assess the damage because of a limited view from the command post. In order to fill the gap "understanding the incident" he used activities and cues to understand the sub-gaps

"incident scale", "unknown risks" and "resource requirements". All three sub-gaps are elements that contribute to comprehending the bigger picture of the overall incident.
This model is mainly relevant for crew leaders and incident commanders when they arrive on scene at the beginning of the incident response or at a later stage to take over from the current commander.

5.3.6.1 Data example

The following example in Table 5-11 illustrates how the process diagram was derived from the interview data.

The example shows how a commander is driven by a lack of information on the incident to do a reconnaissance tour and build up an understanding of the incident from many pieces of information. During his reconnaissance mission he collects and assembles cues on the risk on site (damage, debris and jumpers), the scale of the incident determined by the damage of the building and number of casualties as well as resource requirements to deal with the incident. All three sub-gaps are combined to build up a greater understanding of the overall incident.
In episode 32 the Chief of Safety was asked by a commander to check out conditions in the stairwells and on some floors so that a picture of the safety situation can be build up. This equates to filling the gap of "understanding the incident" by filling the sub-gaps "unknown locations" and "unknown risks".

There were no case specialities or exceptions found for the multiple gap process.

5.3.6.2 Critique

It must be acknowledged that the definition of sensemaking challenges/gaps influences the details of the multiple gap diagrams. What sub-gaps are found in the data depends on which overall gaps were defined or discovered during the analysis process. This could determine how many sub-gaps are found, if any at all. If gaps are defined at a high level then it seems more likely to identify smaller gaps that are components. However, this does not change the general insight that there seem to be some sensemaking challenges that consist of several elements or different aspects. Understanding of each aspect contributes to assembling a bigger picture or understanding of the situation. For example, the UK Fire & Rescue Services train their members to first assess the Incident, Resources and Hazards (IRH) at arrival on scene (personal communication with a member of the UK F&R Services). Each of these elements has several sub-components that are assessed. Together they should contribute to create an understanding of the overall incident that allows for formulation of an adequate response.

5.3.6.3 Summary

The multiple gap process is characterised by one gap that has many sub-gaps (see Table 5-3). Multiple input is required from multiple sources to cover many aspects of a situation that need to be considered to fill different gaps. The process is applicable to situations where a sensemaking challenge consists of several sub-challenges. The process followed to address each gap might follow either of the previously described variations, i.e. emergent, simple, multiple stage or multiple input process.

<table>
<tr><th>Interview data - Episode 40</th><th>Process elements</th><th>Sensemaking process diagram</th></tr>
<tr>
<td>I told Chief Ganci I was going to quickly walk around the perimeter of the Trade Center to assess the degree of damage to the two towers, because our vantage point on West Street only allowed us a view of the west side of the building I took my aide with me. We walked east on Vesey Street, stopped in front of 7 World Trade Center to speak to EMS Chief Peruggia, who gave me a quick update about victims on that side of the building .
Q. What was that update if you recall?
A. He told me how many jumpers he felt had hit the plaza, which we knew we couldn't help and that the people that were already injured were being removed to where the ambulances were staging, which was north of the Trade Center on West Street. I don't recall him giving me any number of people injured.
We stepped over small airplane aviation parts, on Vesey, continued west, continued looking at the building. I looked up at the south tower and could see that it was more heavily damaged than we could tell from our west vantage point. That the second plane had - although it hit from the south, it also did a great deal of damage to the north part of the building. As I got on to Church Street, I walked south on Church towards Liberty, where I was going to turn right. I looked up at the east side of the south tower and found that to be also very heavily damaged, which we couldn't see. I was going to report that information back to Chief Ganci.</td>
<td>Sensemaking context – Information load low
Sensemaking gap – Understanding the incident

Sensemaking sub-gap 1 – unknown risk

Sensemaking sub-gap 2 – resource requirements

Sensemaking sub-gap 1 – unknown risk

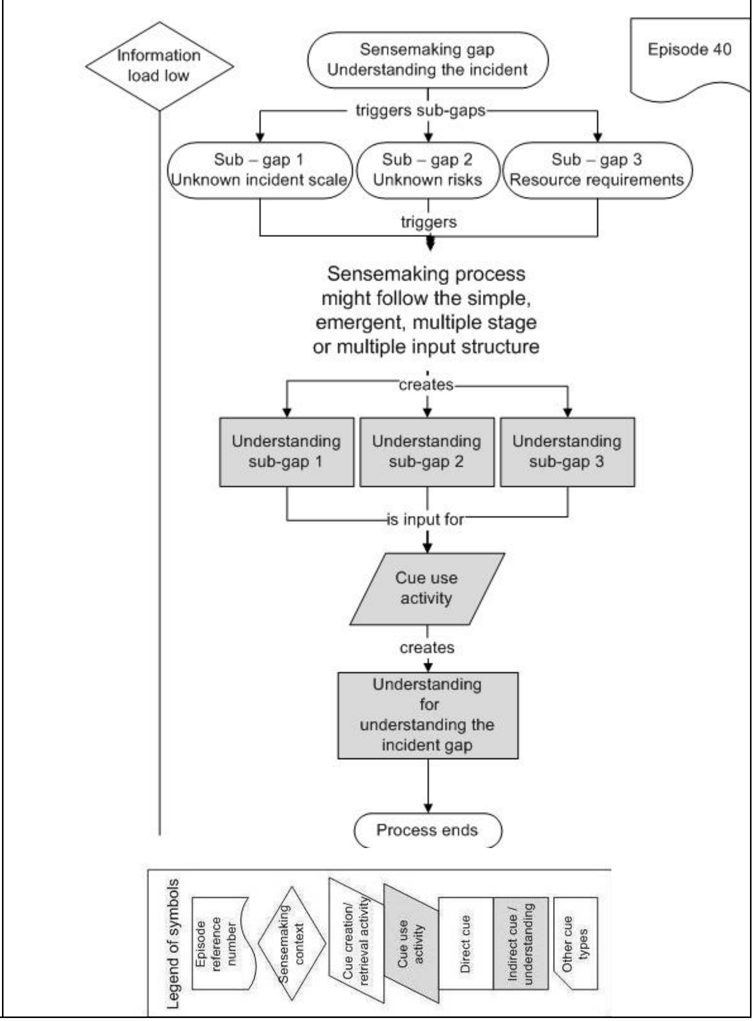
Sensemaking sub-gap 2 – resource requirements
Sensemaking sub-gap 3 – unknown incident scale</td>
<td>
</td>
</tr>
</table>

Table 5-11 - From interview data to process diagram - The multiple gap sensemaking process - example

5.3.7 Gap-triggers-gap process

The gap-triggers-gap process was identified six times in the data and is the second of two meta-models (see Table 5-3). This means that the sensemaking process might follow any of the four previously presented variations.

It was discovered that a successful sensemaking process can close the original gap in understanding and simultaneously trigger a new one, i.e. gap-triggers-gap (see Figure 5-6). In some episodes it was found that new meaning was established in ambiguous situations. However, the established meaning triggered new questions. It was a characteristic of these episodes that an initial understanding of what is going on was achieved. The new gap in these instances was that of "unknown risk". In one episode a fire chief gained initial understanding that a plane had hit one of the towers, i.e. what had happened. Then he was trying to figure out the scale of the incident in terms of required resources to respond to the incident. The follow-up questions do not arise or cannot be answered before the original initial explanation or understanding is gained.

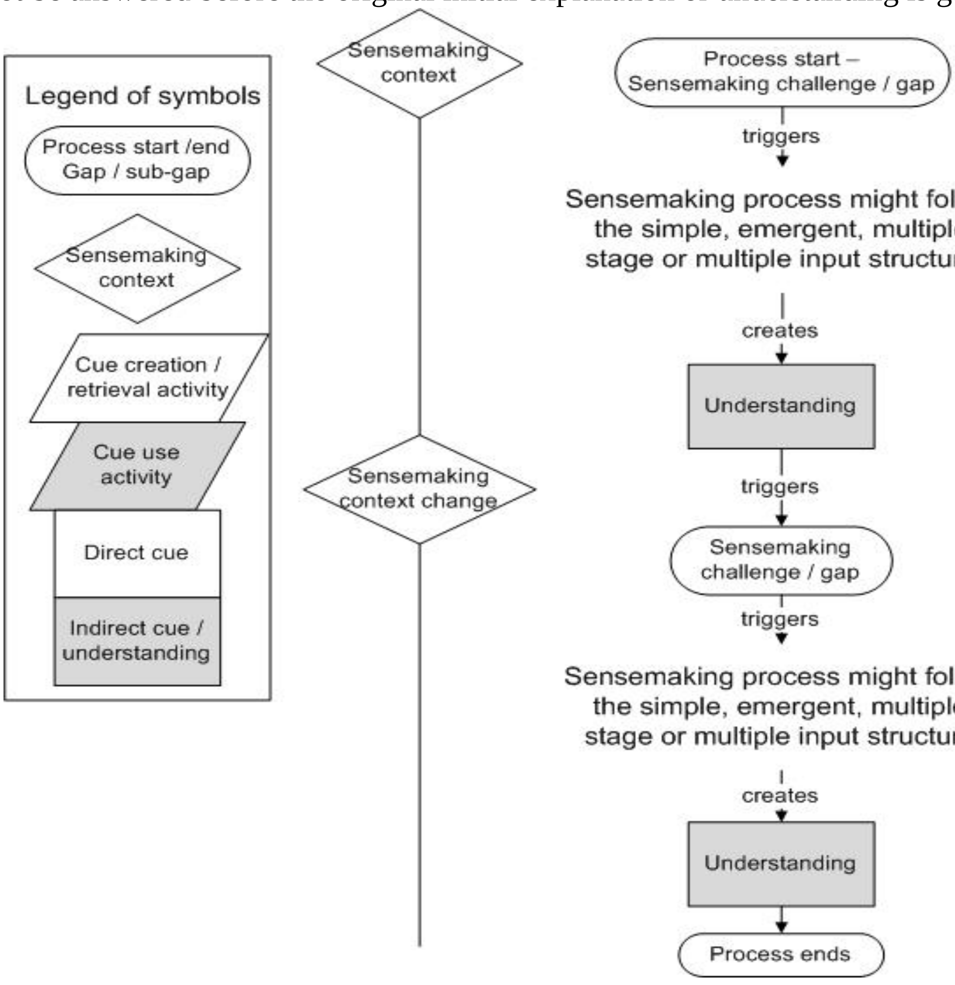


Figure 5-6 – Gap-triggers-gap process

5.3.7.1 Data example

The following example in Table 5-12 illustrates how the process diagram was derived from the interview data.

The example illustrates how two gaps are filled in a row. The first gap is about understanding what the situation of the collapsing tower means for the individual. In this case the simple process structure is followed to arrive at the understanding that he will be overcome by the debris cloud of the collapsing building, i.e. expectation of what is going to happen. This triggers a change of sensemaking context to effect uncertainty and “unknown risk” as a new gap, i.e. it is not clear what material the cloud contains and whether it is going to be harmful. The emergent process structure is followed, including observation of actual cloud content and a projection loop of what else might be contained in the cloud. The insight gained is that he is presently in a dangerous location.
The episode is a process with two stages, i.e. the first stage (gap) about understanding what is currently going on and the second stage (gap) about understanding the real or potential risks. A change in sensemaking context occurs with the second gap.

In all episodes that belong to the gap-triggers-gap process, the first gap was about understanding what is happening, followed by “unknown risk” as second gap (episode 25, 28, 29, 36, 44). All of them had a sensemaking context change in common. As another similarity, the first gap started as data driven sensemaking and the second gap was goal driven sensemaking.

5.3.7.2 Critique

A possible critique of the gap-triggers-gap process is its similarity to the multiple stage model as well as the definition of sensemaking gaps.

Whereas the multiple stage model follows the same structure it is not the case in the gap-triggers-gap process. Here, the researcher found the combination of different process variations: simple - emergent (episode 25), emergent – simple (episode 28), emergent – multiple stage (episode 36) and simple – multiple stage (episode 44).
This shows that the multiple stage process is not the only possible structure to explain how understanding progresses through stages. It can also be through the combination of different process models.

There are three episodes that were initially coded as gap-triggers-gap process but later changed to the multiple stage process. Episode 7, 9 and 23 comprise two stages, each following the structure of the simple process. The gap-triggers-gap process can follow the simple structure in both gaps as can the multiple stage process. Distinguishing between the two now depends on how sensemaking challenges/gaps are defined. If “unknown risk” had not been created as a sensemaking challenge, then the second stage of the process would not have been coded as a new gap but just as natural continuation of the multiple stage model. Thus, ambiguity for coding and diagramming exists in this case.However, this does not affect the insight that sensemaking progresses in stages with a change in focus between the stages.

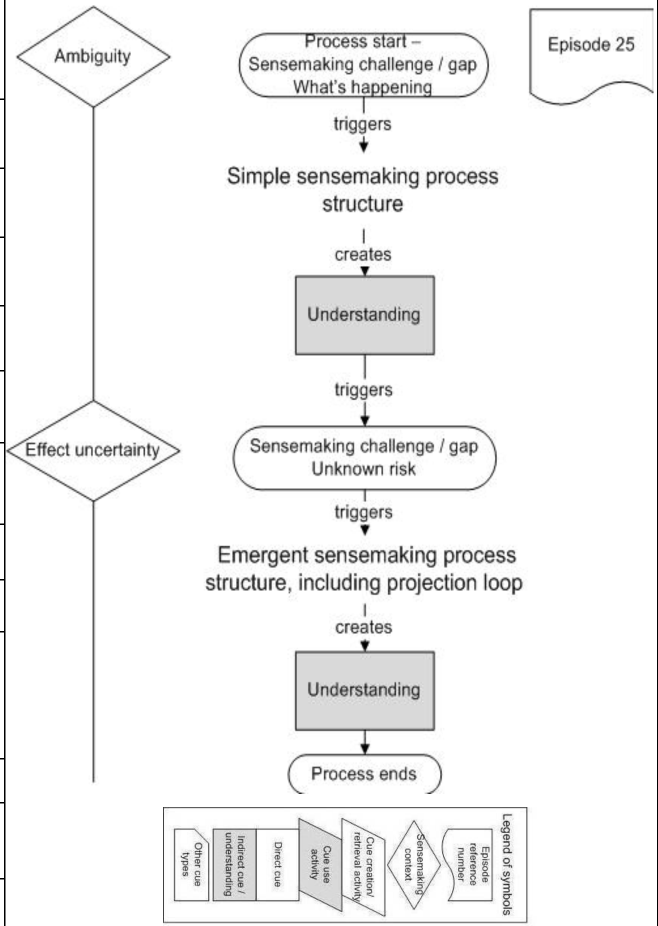
Interview data - Episode 25	Process elements	Sensemaking process diagram
And the building started falling and I started running and a lot of people started running. Whoever was around me started running. Q. Northbound? A. Northbound. We were running northbound up West Street.	Sensemaking context – Ambiguity Sensemaking gap 1 – What's happening	
At one point I could turn around. I **turned around over my shoulder and I just saw**	Cue creation activity – observation	
this cloud. I mean, the building collapsed. **There was a cloud coming at you**.	Indirect cue – cloud speed	
You knew you couldn't outrun the cloud. You just **kept on running trying to get away** from it,	Indirect cue – own speed	
but **you're not going to outrun it**,	Cue use activity – comparison, inference	
so you kind **of resign yourself to the fact that you're going to be overcome by the cloud**.	Understanding - expectation	
You **don't know what's in the cloud**.	Sensemaking context – Effect uncertainty Sensemaking gap 2 – Unknown risk	
You **saw**	Cue creation activity – observation	
a lot of **papers flying around in the cloud**,	Indirect cue – falling objects	
but you didn't know what solid material was in the cloud, **what structural members or facade was in the cloud that could be coming at you**, so that you just kept on going.	Projection loop – what might be	
You're overcome by the cloud. **You heard**	Cue creation activity – listening	
things hitting around you and	Indirect cue – falling debris	
you say to yourself **I hope nothing hits me**.	Cue use activity – risk assessment Understanding – hazard zone	

Table 5-12 - From interview data to process diagram - The gap triggers gap process – example

5.3.7.3 Summary

The gap-triggers-gap process was found where the first gap is related to understanding the context of what is happening. Closing one gap immediately triggers a new one. This process is closely related to the emergent and multiple stage model where the sensemaking process is split into several parts. The process followed to address each gap might follow either of the previously described variations.

5.4 Insights and summary of process variations

Similarities and differences between process models are summarised in this section. It was shown that all process models have a sequence of components in common: sensemaking context - cue creation/retrieval activity - indirect/direct cues obtained – sensemaking activity – understanding. This is the structure of the simple process. Data examples were used to demonstrate that the various stages of other models and loops follow the same structure. However, the second stage of a process might not begin with sensemaking context as element. New, more complex process varieties are created through a combination of several simple structures. Thus, the structure of the simple process is a basic building block for other process variations.

Differences in process structure have several reasons as outlined in Table 5-3:
When one cue use activity is sufficient to gain satisfactory understanding then the simple process is followed. It is not difficult to derive meaning. There is no need to go through additional loops for data collection or clarification and no context changes occur.
The emergent process is relevant for situations where the gained understanding has limitations. If understanding is implausible, unsatisfactory or an assumption, then one or multiple sensemaking loop(s) follow to address this limitation through additional data collection, clarification, confirmation and testing. The limitation is a reflection of the sensemaking context. For example, if an attempt to understand ambiguous information is not successful, then ambiguity is not reduced and remains as sensemaking context. Another attempt to resolve ambiguity is made, e.g. clarification or confirmation. Alternatively, an attempt to explain novel cues can result in an unconfirmed assumption. The sensemaking context might now change from “novel cues noticed” to “plausibility”, triggering a loop to test the assumption on plausibility. Thus, understanding that has a limitation attached or results in a change of sensemaking context triggers process loops.
The multiple stage process covers situations where understanding gained at a first process stage is required to make sense of a different aspect of the situation at the second stage. A change of the sensemaking context might occur between the two stages, e.g. from “novel cues noticed” to “effect uncertainty”. This is the case when a situation is understood at the first stage and then sensemaking of consequences occurs. The second stage of the model has a new purpose, i.e. building on stage 1 insight to take understanding further at stage 2 of the process.
The multiple input generation process covers situations where multiple inputs from multiple sources are required to make sense of a situation. Here, multiple components are required to build up a bigger picture to address a single gap, e.g. state of command

structure. If the situation consists of multiple gaps, e.g. risks, resources, hazards and task progress, then the multiple gap process is followed.

To summarise, the sensemaking process

- Has a basic structure
- Has at least six structural variations resulting from combining the basic structure in different ways
    - Basic process sequence (simple process)
    - Dealing with limitations of understanding (emergent process)
    - Taking understanding further (multiple stage process)
    - Considering many aspects of a situation (multiple input and multiple gap process)
    - Dealing with new challenges as consequences of gained understanding (gap triggers gap process)
- Has at least one stage
- Can be fragmented, i.e. the complete process might consist of several individual fragments which can be a combination of identified process variations
- Is characterised by (interim) understanding at each stage, which might be
    - Limited (emergent process)
        - Process continues to address limitation
    - Satisfactory
        - Process might stop
        - Process might continue (multiple stage, multiple input, gap triggers gap, multiple gap)
            - To improve current understanding
            - Address another aspect of the situation
            - Address a new sensemaking challenge

The finding on several stages in the process triggered the questions of what the stages are about and why they are triggered, i.e. underlying mechanisms. This is addressed in the following chapter 6.

However, the analysis in chapter 5 has already resulted in a number of suspected underlying mechanisms that could explain different stages in the processes:

- Current level of understanding (emergent process)
- Change in sensemaking context (emergent process)
- Change from data to goal driven sensemaking (multiple stage and gap triggers gap process)
- Characteristics of cues at the end of a process stage, i.e. unsatisfactory, non-definitive insight (emergent process)
- Change in focus on another aspect of a situation (multiple stage and multiple gap process)
- Number of gaps related to the situation (gap triggers gap and multiple gap process)

6 Mechanisms underlying the process structure

Chapter 5 showed that the sensemaking process is characterised by different stages. These stages seemed to be tied to gaining different types of understanding, e.g. improving it or focusing on a different aspect of the situation.
What the process stages are about needs to be analysed before the question of underlying mechanisms can be answered. Thus, part 1 of this chapter outlines results on what understanding is gained at each process stage.
Part 2 presents findings on the underlying mechanisms based on the analysis of four process variations (simple, emergent, multiple stage and multiple input generation).

Part 1 of the chapter presents

- An overview of a seven level hierarchy of understanding (section 6.1),
- Details on the seven levels, including examples from data (section 6.1.1 - 6.1.7),
- Six different ways in which understanding evolves (section 6.1.8).

Part 2 presents

- Findings on underlying mechanisms by process variation (section 6.2.2 - 6.2.5)

This is followed by a summary of insights, showing three groups of underlying mechanisms (section 6.3).

6.1 Part 1 - Seven levels of understanding

Table 6-1 shows the developed hierarchy of understanding that consists of seven levels. The hierarchy can be summarised by saying that the levels move from understanding <u>that</u> something is happening (level 0) to <u>what might be</u> happening (level 1) to <u>what is</u> actually going on (level 4) to understanding <u>implications</u> (level 3) to what <u>might be done</u> next (level 4) to understanding the <u>suitability of a course of action</u> (level 5) to understanding <u>progress on performing</u> an action (level 6). The categories will be presented in the following.

Levels of understanding	Total (128)	%
Level 0 - something happens	8	6.25
Level 1 - what might happen	20	15.63
Level 2 - what is happening	48	37.50
Level 3 - consequences	26	20.31
Level 4 - option generation	16	12.50
Level 5 - option evaluation	7	5.47
Level 6 - performance evaluation	3	2.34

Table 6-1 - Levels of understanding across interview episodes - frequencies and percentages

The following Table 6-2 provides a summary of what is understood at each level, level properties, activities to gain understanding and abilities associated with understanding.

Level name	Understanding what	Level properties	Activities to gain understanding	Understanding expressed by ability to…
Level 0 - Understanding that something is happening	Situational development or situation dynamics change with potential need to act immediately;	Ambiguity or uncertainty triggered; relevant cues might be indirectly available; Cues perceived and bracketed;	Perceive (unusual) cues; Interpret actions of people; Relate reactions of people to perceived cues	Describe the perceived cue; Trust actions and instructions of others; Imitate behaviour; Ask further questions
Level 1 – Understanding what might be happening	Initial explanation or assumption about what is going on, a cause, state of operation or resources	Uncertainty and ambiguity still prevail, need for confirmation; Unverified information, assumptions, explanations, hypotheses, speculation	Observe surrounding; receive situation up-dates, reports; Collect information; create and compare explanations for plausibility	Recognise: quality of information, explanation, need for confirmation or additional data collection, that we are not yet dealing with facts
Level 2 - What is happening	Actual state, cause, ongoing development, severity of the situation; Real explanation for noticed cues (as opposed to assumption)	Ambiguity, uncertainty reduced; Effect uncertainty as new property of the situation; Established facts (might be misinterpretation)	Data collection, confirmation, explanation loops; Compare new cues with level 1 or 2 understanding (support, up-date or disprove)	Evaluate quality and modify current understanding; Use experience and cues to create explanation; Take action based on current understanding
Level 3 – Understanding consequences	Implications of past event or current situation (to oneself), as projected future state; Situation alignment with goal	Effect uncertainty reduced, response uncertainty triggered; Situation risks, might rule out an option for course of action	Use mental projection, scenarios, knowledge to derive consequences; analyse surrounding; Risk assessment	Define action needs and goals for option search; Evaluate gravity, impact, probability; Apply training to respond
Level 4 - Option generation	What a potential option is; What a real option is; What not an option is; Availability of an option	Response uncertainty; Instant evaluation (level 5); Goal is guiding option generation; Assumptions about options; Option is directly acted upon	Observing surrounding terrain, comparing for goal fulfilment Creating mental scenario and assumptions; Evaluation if option really exists	Identify need for option evaluation; Formulate search criteria (goal); Relate function of objects to goals; Mentally project
Level 5 - Option evaluation	Suitability, viability of an option, of pursuing an option; Risk associated with option; If option can be carried out and consequences	If option good, then reduction of response uncertainty, other drop to level 4 and uncertainty continues; option alignment with a goal	Assessing option against criteria; Evaluation as mental projection, physical trial; Risk assessment, problem anticipation	Justify if option leads to goal achievement; Integrate goal, evaluation criteria and foreseen or experienced action of carrying out the option
Level 6 – Performance evaluation	If the option works; Partial achievement	Characterised by performance uncertainty; Rapid succession of sensing, acting cycles; Creation of feedback	Physically trying out an option; Sensing to generate new cues; Find indicators that action delivers desired results	Understand if action has the desired, the progress made, what cues indicate achievement

Table 6-2 - Overview of seven levels of understanding, related properties, activities and abilities

The above Table 6-1 shows how many instances of each level of understanding were found in the data (total number and percentages). A detailed table for each of the 7 levels can be found in Appendix D1-D7, showing from which episode the table content originates.

In the following sections each level is described and a data example is given to show the link between the interview data, process diagrams and levels of understanding. For each episode the process diagrams were up-dated, showing which parts of the process correspond to which level of understanding, illustrating how understanding evolves.

6.1.1 Level 0 – Cue perception - Understanding that something is happening

Level 0 is characterised by understanding that something is happening. However, assumptions or explanations about what might be happening are not yet formulated. See Appendix D1 for details on what is understood at level 0, the level properties, activities to gain understanding and the related abilities.

What is understood and level properties

The understanding gained, based on the perception of some cues, is that there is a situational development as well as that there might be a need for immediate action. The need to take immediate action because of a situation change would not be alien to an incident responder in the fire services. As the situation might develop very quickly there might be no time to ask questions or collect more data, but action is required first. Cues in the environment are available, it is possible to notice and perceived them, attention is focused on them but their meaning is not yet clear. One might have an expectation or assumption that something happens but not yet an idea of what is going on.

Although one might argue that cue awareness is just a trigger for an effort to develop understanding, it is argued here that this level is already a specific form of understanding. This is based on the earlier assumption that understanding is like an ability. The researcher found that people are able to act although they do not understand what is going on. This is illustrated by two interview episodes about the collapse of one of the towers. In both cases people were in conversation with colleagues, standing with their backs to the towers. In one case a loud noise was heard, people shouted to run away and then everybody started running. In the other case a terrified look on the colleague’s face and him starting to run away triggered the action to run away. In both cases no additional information was collected on what was happening, not even turning around to look at what is going on. For the interviewees the meaning of cues was only indirectly available through the reaction of other people. This understanding was that the situation is changing rapidly in a way that requires immediate action.

6.1.2 Level 1 – Basic understanding – what might be happening

Understanding at level 1 is characterised by basic understanding in the form of an initial explanation or assumption about what might be going on. However, understanding is limited, speculative and still unconfirmed at this stage.
See Appendix D2 for details on what is understood at level 1, the level properties, activities to gain understanding and the related abilities.

What is understood and level properties
Understanding at level 1 is characterised as initial explanation or assumption about either what the incident or current situation is about, what caused it, the current state of operations or resources, resource location or requirement. In most instances this level marks the continuation from level 0. Properties of level 1 understanding are that ambiguity and uncertainty about the situation state prevail because the initial explanation, assumption or incoming information is not yet confirmed. However, a first reference point in form of an unverified explanation or assumption is created to develop understanding further. Assumptions or hypotheses can become substitutes in the absence of verified facts.
It was found that people try to understand a situational state, risk to operation and life, nature of incident, and state of operations. Cause, effect and consequences of the event are not yet known or understood. However, the problem space of what needs to be understood better is framed, in terms of what might be going on. This is an indicator for what activities are required to move on to level 2 understanding, i.e. where explanations are confirmed and one deals with facts.

6.1.3 Level 2 – Improved understanding – what is actually happening

Level 2 of the hierarchy can be described as the level of established facts. It is characterised by understanding of what is believed to be actually happening.
See Appendix D3 for details of what is understood at level 2, the level properties, activities to gain understanding and the related abilities.

What is understood and level properties
Achieving level 2 understanding means a reduction of ambiguity and state uncertainty because a plausible explanation for an event is found. When a situation is observed and it is clear what the obtained cues mean then level 2 is the one about established facts. Although facts are established at this level, effect uncertainty might be a new property of the situation. This means that once one knows what is going on there are new questions about consequences of this situation.
However, there were also instances where interviewees were not 100% sure about the situation but had confidence that their explanation was correct or close to reality. People might try and develop multiple plausible sounding scenarios to explain what is happening. If correct factual information is available but it is not believed then it does not constitute level 2 understanding because to achieve this level one must be convinced to have the correct and plausible picture of the situation. If this is not the case then understanding is rather situated at level 0 or 1. This also indicates that there might be significant differences between the real situation and the understanding achieved. The

levels proposed here are subjective in that they reflect the understanding gained by a person, neglecting whether it is the correct or wrong understanding.

6.1.4 Level 3 – Understanding implications

Level 3 of the hierarchy can be described as the level of understanding the consequences of an event.
See Appendix D4 for details on what is understood at level 3, the level properties, activities to gain understanding and the related abilities.

What is understood and level properties

Level 3 of the hierarchy is characterised by reduction of effect uncertainty through understanding consequences for one's own as well as the operational context. This level is dominated by assessment activities to gain understanding of situational effects on personal as well as operational safety, i.e. risks from objects, smoke, fire, explosions and dust.
This also includes understanding consequences of consequences. For instance, the implication from an explosion is that debris will fall over a large area, which causes a sudden widening of the hazard zone around the explosion with the implication that people in this zone immediately need shelter or get out of there. It was also found that the severity and immediacy of effects were assessed.

One example from the data is the projection of the collapse trajectory of a tower to realise that the safety distance to the collapse zone needs to be increased immediately. In another instance it involved the relocation of a command post in anticipation of safety implications from falling debris. In another case a re-assessment of consequences was done based on a situation up-date to find out if the current response was still appropriate.

6.1.5 Level 4 – Option generation – what might be done next

Level 3 understanding was about understanding implications of an event. Level 4 of the hierarchy can be described as the level of understanding what options exists for taking a course of action.
See Appendix D5 for details on what is understood at level 4, the level properties, activities to gain understanding and the related abilities.

What is understood and level properties

Level 4 cannot be understood in isolation because it is closely related to the previous level 3 (implications of an event) and the following level 5 (option evaluation). It had to be analysed and presented by referring to level 3 and 5 because there are several ways in which options are understood.

At level 4 it is understood whether an option is available, if it is a potential, real or no option. Most of the instances that fall into this category are atypical situations that have not been experienced before. Thus, the part of the recognition primed decision (RPD) model (Klein, 1998; Klein, 1997) where people recognise a situation as typical and select the according course of action is not applicable here. Rather one needs to create a possible course of action and understand not only this option but also whether it really exists.

In most episodes understanding an option was gained from a combination of level 4 with level 3 and/or level 5.
Comparison of an option with goals originating from level 3 (episode 6, 43, 49) is one way how options are understood. In many instances an option was immediately ruled out as a consequence of understanding implications of a situation at level 3 (episode 1, 6, 16, 34, 36, 37, 43, 49), e.g. initial assessment of the damage and fire in the towers leads to the insight that extinguishing the fire is not an option because of its large scale.
Options were also ruled out as not viable after evaluation at level 5 (episode 26, 31, 36, 44) or unsuccessful implementation of an option at level 6 (episode 24).
If a potential option is found, then the immediate next step is to evaluate it at level 5 (episode 26, 31, 34, 36, 37, 44). In one case the multitude of cues made a compelling case in favour of an option (episode 47). In two cases the option was not understood because sensemaking was interrupted (episode 6, 16).
In the majority of above cited episodes it seemed to be evident to interviewee that an option exists or could be found without major difficulties. However, in two episodes evidence was found for deliberately testing if an option exists at all (episode 34, 37). This means that an assumption about the existence of an option existed but it had to be confirmed. Consequently, level 4 includes understanding whether an option really exists.

6.1.6 Level 5 – Option evaluation – what actually works

Level 5 of the hierarchy can be described as the level of option evaluation and understanding whether it is viable.
See Appendix D6 for details on what is understood at level 5, the level properties, activities to gain understanding and the related abilities.

What is understood and level properties

Level 5 is characterised by understanding if an option can be carried out and whether it is worth pursuing as well as the associated risks and consequences.
The level properties are a reduction of response uncertainty if evaluation is in favour of the option. However, if the option is ruled out, then understanding drops to level 4 and response uncertainty prevails. There are also differences in how the evaluation is carried out, i.e. either physically trying out or mentally simulating.

6.1.7 Level 6 – Performance evaluation

Level 6 of the hierarchy can be described as the level of performance evaluation and understanding if a course of action is successful.
See Appendix D7 for details on what is understood at level 6, the level properties, activities to gain understanding and the related abilities.

What is understood and level properties

Level 6 becomes relevant when a course of action is started. Here it can be important to understand if the course of action delivers the desired results. At this level it is understood if an option really works the way it was anticipated as well as the progress one makes, e.g. something might indicate a partial achievement.

The level is characterised by performance uncertainty, a rapid succession of sensing and acting steps as well as the generation of feedback.

Examples for level 6 are episodes 48 and 56, both about the same situation. Interviewees sought cover from the collapsing tower in a garage. The dust cloud resulted in near zero visibility and bad breathing conditions, forcing them to find a way outside. Both compared options of going further inside the garage or leaving the way they came in, although the exit might be blocked by debris and conditions outside are not clear. They opt for going outside.

> Episode 48: "*There was some debris that I was able to get over. Before I knew it, I was walking up the ramp again. I kind of assumed I was outside and I kept walking and I walked into a tree. That was it.*"
>
> Episode 56: *"and it was so dark, I could hear other voices around me, there was also other people coming out that same way, but it was so pitch black that I did not know I was outside of the garage until I walked into a tree on the sidewalk, and I actually felt good about that. At least I knew I was outside."*

They cannot see where they are going and therefore need to feel and listen to create cues that might indicate whether they are already outside (getting over debris, voices of people going in the same direction, feeling the incline of the ramp, walking into a tree). Every new cue seems to be an indicator and feedback for partial or complete achievement.

6.1.8 Movement of understanding between the levels

The previous section on levels of understanding in process variation showed evidence that understanding can move across various levels and in several directions. In this section the dynamics of understanding are presented, summarising in which directions it moves.

In the 59 sensemaking episodes the following developments of understanding were found:

- Limited to 1 level: 16 cases
- Across 2 levels: 25 cases
- Across 3 levels: 12 cases
- Across 4 levels: 4 cases
- Across 5 levels: 2 cases

Six different ways in which understanding developed were identified in the interviews (see Figure 6-1).

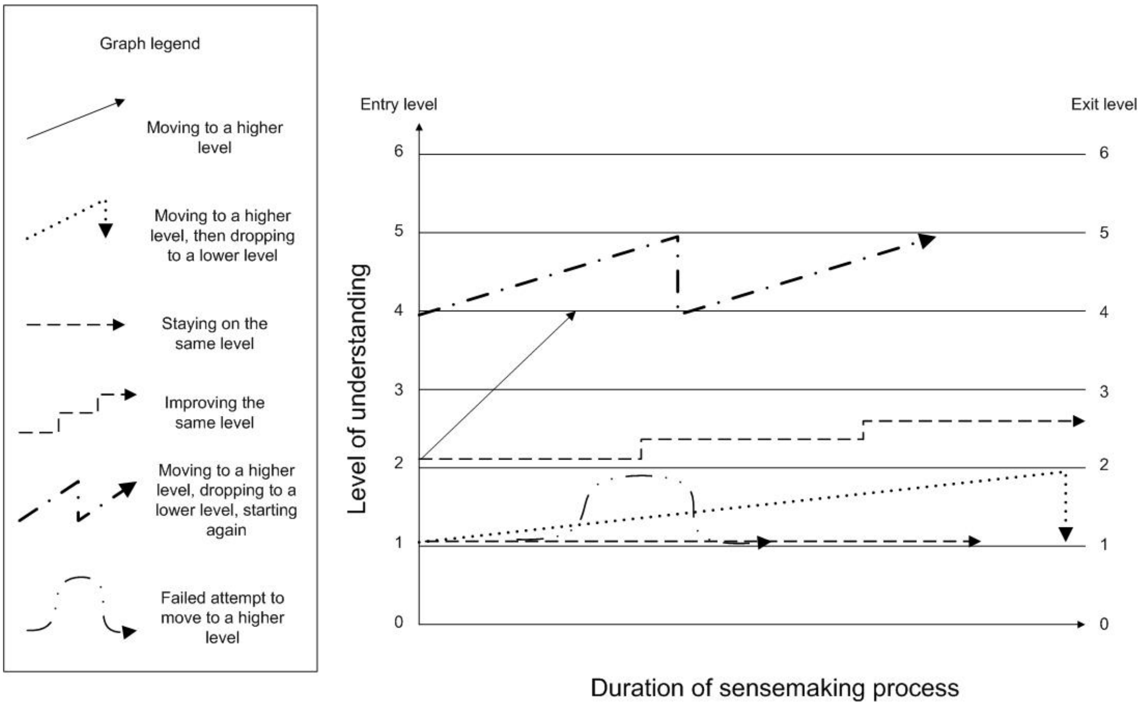


Figure 6-1 - Movement of understanding across six levels

The entry level depended on what interviewees described. Sometimes a move from level 2 to 3 or 4 to 5 was described without mentioning the previous thoughts. This might mean that sensemaking happened at lower levels of understanding but was not described.
The horizontal axis of the graph in Figure 6-1 shows the duration of the sensemaking process. The length of arrows varies to illustrate that each sensemaking process can have a different duration.

Most episodes refer to moving to a higher level. Examples for this case are episode 1, 6, 7, 9 and 11 where understanding of an event at level 2 led to understanding consequences (level 3). Actions are taken based on this insight.

However, understanding might drop to a lower level as well. This was the case in episode 54, where a chief thought that the buildings were structurally sound for at least 3 hours. After some time new information arrived that the buildings are not structurally sound any more (this was after considerably less than 3 hours into the incident). At this point understanding dropped from level 2 to level 1 because the information was unconfirmed. What followed were two unsuccessful attempts to confirm this information. This illustrates a failed attempt to move to a higher level.

Understanding might also stay on the same level. This is mostly the case for the simple sensemaking process variation which covers usually only 1 level. For example, an explanation for an event is found and this brings sensemaking to an end.

In many episode instances of improving the same level were found. This was where single and multiple data collection loops were used to improve level 2 understanding (episode 3, 8, 10, 22, 28, 32, 38, 40, 42, 53). Thus, there might be a gradual improvement of a single level.

There is also an instance where understanding moves to a higher level, drops back and is improved again. This was the case in episode 36 where an option for a course of action was twice found (level 4) and dismissed as unviable after evaluation (level 5) before the 3rd attempt led to action after evaluation. The movement between the levels was 4 → 5 → 4 → 5 → 4 → 5 → action.

Other failed attempts to move to a higher level of understanding were found in episodes 4, 5, 45 and 58 where data collection and explanation loops were not successful. In these episodes understanding remained at the same level.

Different combinations of the arrows shown in Figure 6-1 within one sensemaking episode are possible. Sometimes moving to a higher level includes several unsuccessful attempts.

6.2 Part 2 – Underlying mechanisms by process variation

The purpose of part 2 in this chapter is to present underlying mechanisms in the previously identified process variations.

Part 2 comprises
- A brief summary of insights so far (section 6.2.1),
- Findings on the four suspected mechanisms and additionally identified mechanisms in each of the four process variations (section 6.2.2 - 6.2.5).
- A summary of insights, where results from chapter 5 and 6 are combined (section 6.3).

The findings on mechanisms in sections 6.2.2 - 6.2.5 are presented in a specific format:
- Summary of what mechanisms were found in a process variation and when they occur. This is referred to as “the usual pattern”.
- Results from the analysis about each of the four suspected mechanisms from chapter 3 and 5 (level of understanding, sensemaking context, data/goal driven sensemaking and specific cue types) are presented.
- Explanation of mechanisms that trigger the first process stage.
- Explanation of mechanisms that trigger the second process stage, which includes findings on other than the four suspected mechanisms.

6.2.1 Insights so far

Based on the analysis it was shown that the sensemaking process occurs in stages (chapter 5) and that different levels of understanding are gained at the end of each stage (chapter 6 part 1). This enabled analysis of what happens between the process stages in terms of underlying mechanisms.

As previously described in the second part of the literature review (chapter 3) and the results on process variations (chapter 5) it is suspected that level of understanding, sensemaking context, data/goal driven sensemaking and specific cue types might be mechanisms that trigger sensemaking processes and their stages.

Four process variations (simple, emergent, multiple stage and multiple input generation) were analysed based on the assumption that the four above mentioned factors might be explanatory mechanisms for stages. They might not explain which process variation is triggered but this is not important here as the goal of this part of the thesis was not prediction.
The above factors were traced in the episodes for each of the four process variations to see how they develop (see Appendix D8 for analysis of processes on the four suspected mechanisms and Appendix D9 – D12 for analysis of data on other mechanisms).

6.2.2 Mechanisms in the emergent process

The purpose of this section is to report findings on the four suspected mechanisms in the emergent process variation and present additional mechanisms. For more details on analysis see Appendix D8 as well as Appendix D9 – D12.

6.2.2.1 The usual pattern

Usually there is

- A move to a higher level of understanding, at least an attempt,
- A change of sensemaking context,
- A change from data to goal driven sensemaking,
- A cue type that indicates another process stage.

Moving from one level to another is explained here as the need to

- Overcome lack of cues (at level 0),
- Convert assumptions into facts (moving from level 1 to 2),
- Build a more complete situational picture (improving level 2),
- Understand if option is useful (moving from level 4 to 5),
- Understand if options really exist (at level 4),
- Understand if alternative options exist (if level 5 and 6 are unsatisfactory).

These needs are based around situational factors

- Personal and crew safety, risks,
- Operational implications, e.g. need to respond, changing response,
- Personal involvement.

6.2.2.2 The four suspected mechanisms

<u>Levels of understanding</u>

Levels 1, 2, 4 and 5 were the main levels of understanding that were found in the emergent process.

The first stage is about reaching one level of understanding and the second is about reaching a higher level or at least improve the same level:

- reaching level 1 in the first stage and moving to level 2 in the second stage (episode 10, 12, 13, 17, 21, 35, 47),
- reaching level 2 in the first stage and improving it the second stage (episode 8, 22, 28, 32, 38, 40, 42), or
- reaching level 4 in the first stage and moving to level 5 in the second stage (episode 24, 26, 34, 36, 37).

However, attempts to improve a level are not always successful (episode 5, 45, 54, 51, 13) but might be followed by another attempt (episode 5, 51).

Existence of different levels explains why there are stages in a process, i.e. each stage has a specific purpose:

- Moving to a higher level, e.g. episode 10, 12, 13, 17, 19, 22, 25, 35, 44, 47, 55
- Improving the same level, e.g. episode 3, 8, 10, 22, 28, 32, 38, 40, 42, 53.

Sensemaking context

Every episode starts with a sensemaking context. The following contexts were found to trigger the process:

- Novel cues (episode 3, 5, 10, 12, 13, 15, 17, 21, 22, 28, 29, 36, 37, 47, 51, 54),
- Information load low (episode 8, 32, 38, 40, 45),
- Response uncertainty (episode 24, 26, 34, 36),
- State uncertainty (episode 3, 5, 42),
- Unexpected event (episode 13, 37),
- Ambiguity (episode 35).

It was found that the context that triggered a sensemaking episode can change during the process. Especially, where the first process part is data driven there is usually a sensemaking context change (episode 5, 12, 13, 17, 21, 22, 28, 36, 37, 47, 51, 54, not: 3, 10, 15, 35).

The following context changes were found, i.e. change to:

- Information load low (episode 22, 36),
- Plausibility (episode 12, 13, 37),
- Ambiguity (episode 17, 21, 47, 54),
- State uncertainty (episode 5, 28, 47),
- Surprise (episode 51).

Where the first process part is goal driven already, there does usually not seem to be a sensemaking context change. A change of sensemaking context at the end of the first stage in the emergent process, explains why loops are triggered.

The following Table 6-3 shows what form the limited understanding takes in the emergent process, what new sensemaking context is triggered and what type of loop was caused.

Data collection loops

Data collection loops were mostly associated with an attempt to move from level 0 to level 1, moving from level 1 to level 2 or improving level 2 (episodes 4, 5, 8, 10, 22, 28, 29, 32, 35, 36, 38, 40, 42, 47, 53, 55). This is not surprising as understanding at the lower levels of the hierarchy are characterised by an insufficient or low number of available cues.

Confirmation loops

Confirmation loops were found to be used to confirm initial explanations, assumptions and received information at level 1 and 2 (episode 12, 17, 21, 45) or at level 4 to confirm the existence of an option (episode 34, 37).

Explanation loops

Explanation loops were found were individuals tried to come up with a cause for an event (episode 15, 51). Projection loops to speculate about future consequences (episode 19, 25) and evaluate an option (episode 34, 36)

Limited understanding at the end of the 1st process stage	Sensemaking context changes to…	The loop that is triggered
Limited understanding of situation	Response uncertainty: not sure about available options.	Extension loop
	Effect uncertainty: consequences of current situation not understood	Extension loop
	New gap is triggered.	New episode started.
Explanation, assumption, expectation	Ambiguity: multiple interpretations.	Clarification loop.
	Effect uncertainty: impact of current situation not understood.	Clarification loop, extension loop.
	Plausibility.	Confirmation loop, alternative explanation.
Multiple possible explanations	Ambiguity: unclear which one reflects reality better.	Confirmation loop.
Conflicting explanations	State uncertainty: not sure if situation is changing or not.	Extension loop, confirmation loop.
Information quality or quantity still low	Plausibility.	Confirmation loop.
	State uncertainty: not sure about the real state of the situation.	Extension loop.
Multiple options for course of action	Uncertainty: not sure which one works or is the better one.	Create feedback: trying out, mental simulation.
Unsatisfactory option (evaluation does not deliver desired outcome)	Response uncertainty.	Option generation.

Table 6-3 – Limited understanding in the emergent sensemaking process, change of sensemaking context and triggered loops

To summarise, when a new sensemaking context arises, either at the beginning of the process or in between, then it is likely that a new process or process part is triggered.

Data/Goal driven sensemaking

It was found that sensemaking that follows the emergent process structure can be described as either data driven, goal driven or both. The first stage was usually found to be data driven and the second stage goal driven.

Where the first process part is goal driven already, there does usually not seem to be a sensemaking context change.
A switch from data to goal driven sensemaking was observed between the 1st phase of the process and before entering a loop. Where the first process part is data driven there is usually also a sensemaking context change (episode 5, 12, 13, 17, 21, 22, 28, 36, 37, 47, 51, 54, not: 3, 10, 15, 35)
No instance of a change from goal to data driven sensemaking was found.
In one instance the nature of the task described in the episode led to defining it as both data and goal driven (episode 53). Here, new cues were constantly received to populate the command board at the incident command post and it was the goal of the fire chief to find current information to up-date the board.

To summarise, a switch from data to goal driven sensemaking can indicate that the understanding of cues is not enough but can trigger a deliberate attempt to understand more. This would indicate the beginning of a new process or process stage and might be described as the desire or need to make sense.

Cue types
The limited understanding at the end of the first process stage was characterised by the cue type: “non-definitive”. This emphasises the nature of the limited insight, e.g. only an assumption or an incomplete factual picture. The cue type “unsatisfactory” was used where e.g. the evaluation of an option resulted in dismissing it. The second stage outcome was sometimes an “action” cue. However, action is not always necessary, e.g. when just the meaning of a cue needs to be understood but no action needs to be taken.
In two episodes (28, 36) action preceded understanding (which was at level 0).

Non-definitive and unsatisfactory cues do not trigger anything. However, it is argued here that the perception of a cue as non-definitive or unsatisfactory contributes to seeing a level of understanding as insufficient. This might then indicate the need to correct or improve understanding and thus a new process or process stage. Action cues, however, seem to usually indicate the end of the sensemaking process, as it precedes action.

6.2.2.3 Explaining the first process stage

As described in the previous section, the process was triggered usually by novel cues (data driven) or low information load (goal driven) and resulted in limited insight at the end of the first stage (non-definitive; level 1 or 2).

6.2.2.4 Explaining the second process stage

The question here is about the underlying mechanism that triggers the second process stage. As the analysis in Appendix D8 shows there is not always

- a move to a higher level of understanding,
- a change in sensemaking context,
- a change between data and goal driven sensemaking.

Different combinations are possible, which means that each of the four suspected mechanisms individually is not sufficient to explain why a second process stage occurs.

To cover the episodes where these mechanisms have not been found the researcher returned to the interview data and analysed the situation in which individuals were to find other indicators.

Personal involvement, personal and crew safety as well as operational task requirements were identified as possible explanatory mechanisms (see Appendix D9-D12). This is explained here by asking the questions: What is the need to move from level 1 to 2? What is the need to move from level 2 to an improved level 2? What is the need to move from level 4 to 5?

What is the need to move from level 1 to 2?
A move to level 2 might be explained by the need to convert assumptions into facts.

The relevant episodes were mainly related to dealing with information:

- Need to establish quality and truth of information because of potential operational and safety implication if it was true (episode 45, 54), e.g. rumour of a building being structurally unsound;
- Need to establish if information is true because if it were true then there would be a requirement for incident response (episode 10, 13, 17, 21, 35, 45), e.g. initial information about incident is not believed;
- Need to reduce the number of possible explanations for an event (episode 17);
- Need to validate information received by civilians (episode 4), information might have operational consequences.

What is the need to move from level 2 to an improved level 2?
Improvements of level 2 might be explained by the need to build a more complete factual picture.

The relevant episodes were mainly related to building up a bigger picture of the situation:

- Need to build the bigger picture from many fragmented pieces of information (episode 8, 32, 38, 40, 42), e.g. reconnaissance tour around buildings;
- As time has passed since the last level 2 insight there is a need for facts on how situation is developing (episode 22, 28), e.g. understanding the most recent situation development.

What is the need to move from level 4 to 5?
A move to level 5 might be explained by the need to understand if an option is useful:

- Need to understand if option meets criteria (episode 34, 36);
- Need to find new option if evaluation is unsatisfactory for personal safety reasons (episode 26, 36).

Level 0, 4 and 6

At level 0 there is a general lack of cues on the situation, i.e. a need for cues to make sense exists (episode 29, 36, 47), driven by needs for safety and personal involvement.
At level 4 there might be a need to understand if an option for action really exists (episode 34, 37), driven by needs for safety and personal involvement.
If an action does not have the desired effect (level 6) then there is a need to understand what alternative options exist (episode 24), driven by needs for safety and personal involvement.

6.2.3 Mechanisms in the multiple stage process

The purpose of this section is to report findings on the four suspected mechanisms in the multiple stage process variation and present additional mechanisms. For more details on analysis see Appendix D8 as well as Appendix D9 – D12.

6.2.3.1 The usual pattern

Between process stages there usually is

- A move to a higher level of understanding, at least an attempt
- No change of sensemaking context (if there is then they were descriptors introduced by the researcher)
- No change from data to goal driven sensemaking
- No cue type that indicates another process stage

In contrast to the emergent process the latter three points do not seem to be active mechanisms that explain a transition from one level of understanding to another.

Moving from one level to another is explained here as the need to

- Understand implications from a situation (moving from level 2 to 3)
- Understand if option is useful (moving from level 4 to 5)

These needs are based around other needs

- Personal and crew safety, risks
- Operational implications
- Personal involvement

6.2.3.2 The four suspected mechanisms

Levels of understanding

Level 2, 3, 4 and 5 were the main levels of understanding found in the multiple stage process.

This is reflected in

- reaching level 2 (what is happening) in the first process stage and moving to level 3 (consequences) at the second stage (episode 1, 7, 9, 11, 16, 20, 23, 37, 44, 49),
- reaching level 4 (options) in the first process stage and moving to level 5 (option evaluation) at the second stage (episode 31, 36).

Three episodes (episode 6, 15, 47) represent special cases where the first stage is already about level 3 but in a hypothetical form, i.e. speculating about possible consequences. This might be interpreted as level 1 (what might happen) within level 3. The second stage is about figuring out further consequences from potential consequences, i.e. both stages are about level 3.

The multiple stage process differs from the emergent model in that it was mainly found in moving from level 2 to 3.

Sensemaking context

The following sensemaking contexts were found to trigger the process:

- Novel cue (episode 7, 9, 11, 18, 20, 37, 43, 44, 46, 49),
- Response uncertainty (episode 31, 36, 47),
- State uncertainty (episode 6, 15).

As in the emergent process, there are instances where a sensemaking context change occurs between the two stages. However, a context change does not seem to always occur. Moreover, definite proof for a context change could not be found in the data. Therefore, the context change is marked by a “D” for Descriptor in the provided diagrams to indicate that the researcher introduced it. The following context changes were identified:

- State uncertainty – descriptor (episode 46),
- Effect uncertainty – descriptor (episode 7, 9, 11, 23),
- Response uncertainty – descriptor (episode 43, 49).

If the descriptors are disregarded, then it has to be said that there is no sensemaking context change between the process stages. This would mean that it is not a useful mechanism to explain why the second stage is triggered.

Data/Goal driven sensemaking

It was found that sensemaking was data driven usually where “novel cues” was the context that triggered the process. The process was goal driven from the beginning, where the sensemaking context was

- Information load low (episode 23),
- Response uncertainty (episode 31, 36, 47).

Only one change from data to goal driven was found between the stages. This was with a change to "response uncertainty" to move to level 4 (episode 43).

To summarise, the multiple stage process is either data driven or goal driven but changes from one to the other do not seem to occur between process stages. This means that it is not a useful mechanism to explain why the second stage is triggered. This is in contrast to the emergent process.

Cue types
No pattern was found to explain the second process stage. Rather, the cue types "unsatisfactory" and "action" were found at the end of the second process stage. Where an action followed the gained insight, this understanding was termed "action cue". This can be the case either where an option is found to be useful (level 5) or where consequences of a situation require immediate action (level 3).

To summarise, no specific cue types are found between process stages but at the end of the 2nd stage. This is contrary to the emergent process where the first insight is usually a "non-definitive" cue and indicates that a second process stage might be required.

6.2.3.3 Explaining the first process stage

As described in the previous section, the process was triggered usually by novel cues (data driven) or response uncertainty (goal driven).

6.2.3.4 Explaining the second process stage

The question here is about the underlying mechanism that triggers the second process stage. As the analysis in Appendix D8, D9-D12 and the description above shows there is

- Usually a move to a higher level of understanding,
- No change in sensemaking context between stages,
- No change between data and goal driven sensemaking,
- No specific cue type that would indicate a second stage.

Contrary to the emergent process the latter three mechanisms are not useful to explain the second process stage in the multiple stage process.

This means there must be other factors. The researcher returned to the interview data and analysed the situation in which individuals were to find other indicators.

Personal involvement, personal and crew safety as well as operational task requirements were identified as possible explanatory mechanisms (see Appendix D8). This is explained here by asking the questions: What is the need to move from level 2 to 3? What is the need to move from level 3 to 4? What is the need to move from level 4 to 5?

What is the need to move from level 2 to 3?

A move from level 2 to 3 might be explained by the need to understand implications of a previously understood situation. To understand what the situation means you need to understand what is going on.
In other words the first stage is about figuring out what is going on, the second stage is triggered to establish meaning of that situation in form of implications.

The relevant episodes can be categorised in three groups:

Consequences of factual knowledge in terms of reaching a goal needs to be understood, i.e. level 2 = what is currently known, level 3 = meaning for reaching goal established (episode 16).

What the current situation (development) means needs to be understood with regard to

- Operational effectiveness, e.g. command post location (episode 23), first indication of incident response (episode 49),
- Safety of individuals and crews (episode 9, 11),
- Determining operational response (episode 9, 11, 23, 49).

What the current situation (development) means needs to be understood because of

- Personal involvement (person is potentially directly affected by the situation), e.g. being next to a collapsing building (episode 1, 7, 20, 37, 44),
- Personal and crew health and safety (episode 1, 7, 20, 37, 44),
- Potentially risky situation (episode 1, 7, 20, 37, 44).

What is the need to move from level 4 to 5?

A move from level 4 to level 5 might be explained as the need to understand if an option is useful.

What a possible option for action means needs to be understood because

- Of a need to establish value of option in reaching goal or fitting criteria (episode 31, 36),
- Value of an option needs to be understood because of urgent need for action, personal involvement in a risky situation, for safety reasons to avert harm (episode 31, 36).

6.2.4 Mechanisms in the simple process

The purpose of this section is to report findings on the four suspected mechanisms in the simple process variation and present additional mechanisms. For more details on analysis see Appendix D8 as well as Appendix D9 – D12.

The simple process occurs either as stand alone process or precedes / follows other process variations. There were several reasons for using the simple process as additional variation in episodes. First, it might be that there is a time lag between efforts to understand a situation. For instance, an action was triggered based on understanding and at a later point an up-date of what is going on is required. Alternatively, new cues are noticed at some point but become relevant only at a much later stage of the situation or the simple process is used to integrate several previous insights to derive new meaning. Second, there might be a thematical change in what an individual thinks about, e.g. thinking about a different aspect of a situation. In this case it was assumed that a new sensemaking process is started rather than the previous one continued.

6.2.4.1 The usual pattern

There usually is

- A need to generate new understanding or move to a higher level,
- No change of sensemaking context within the process,
- No change from data to goal driven sensemaking within the process,
- No cue type that indicates another process stage.

The underlying mechanism is explained here as the need

- For more information on current development (at level 0),
- To understand novel cues, rapid situation development or integrate fragments of previous understanding (at level 2),
- Understand implications from a situation (at level 3),
- Understand if option is available (at level 4),
- Understand viability of an option (at level 5),
- To understand if action has desired effect (at level 6).

These needs are based around other needs

- Personal and crew safety, risks,
- Operational requirements and implications,
- Personal involvement in a situation.

6.2.4.2 The four suspected mechanisms

Levels of understanding

All seven levels of understanding were found in simple process structures.

Level 0 was found in episode 15 where observation of a colleague's facial expression, which was a reaction to seeing a tower collapsing, led to understanding that something terrible must be going on.
In episode 2 knowledge and experience were used to come up with an assumption of where the command post might be located, i.e. Level 1.
The observation of new cues often leads to understanding of what is currently going on and can be described as observing facts, e.g. what looks like an explosion must be an explosion. Thus, the simple model was found often when new cues were observed and their meaning derived (episode 19, 20, 25, 41, 44, 57, 59). This includes up-dating earlier understanding when new cues become available at a later point in time (episode 21, 22, 25) as well as correcting earlier understanding (episode 19) and integration of different pieces of level 1 understanding (episode 33). However, the simple process is not always successful, so although new cues are observed they might not be integrated to derive understanding (episode 14).
The simple process also included level 3 as 2nd part of gap triggers gap model (episode 28), level 3 as continuation of level 2 (episode 55), level 3 with following context change and other model to continue at levels 4 and 5 (episode 34), level 4 as continuation of level 3 (episode 6) as well as level 3, 4 and 6 in episode 56.

In three episodes the simple process seemed to include two levels of understanding. In episode 50 new cues were created which related to what is going in the environment and the used to understand consequences of these cues, i.e. level 3. In episodes 31 and 44 cue creation referred to coming up with a possible option for a course of action and cue use to evaluation of the option. That the simple process contained 2 levels of understanding might be the case because the description in the interview data was not detailed enough. Thus, in reality the process might have followed another variation.

Sensemaking context

The sensemaking context for most episodes was "novel cues" (e.g. episode 15, 19, 20, 21, 22, 28, 44, 57, 59), whereas "unexpected event" and "turbulence" had one episode each (14 and 34). All these sensemaking contexts have the confrontation with novel cues in common (turbulence = rapid situation development; unexpected event = a novel situation) that require the construction of understanding.
Sensemaking context changes do not occur during the simple process. Rather, a specific context triggers the process or a context change is the result of the process.

Data / goal driven sensemaking

The majority of episodes that follow the simple process structure were data driven. Only three episodes were goal driven. The sensemaking contexts were low information load (episode 2), response uncertainty (episode 31) and state uncertainty (episode 41). The goals here were to find specific information to understand an event, what the response in a situation might be and how the state of a situation had changed after a development. No changes between contexts were found during the sensemaking episode. Thus, the simple process is either data or goal driven.

Cue properties

Like in the multiple stage process no specific pattern was found. Rather, the cue types "unsatisfactory" and "action" were found at the end of the process.

6.2.4.3 Underlying mechanisms

As there are no stages in the simple process variation there is the question of why it is triggered at all.

At level 0 there is a need

- For more information on current development, needed for personal involvement and safety implications (episode 15).

At level 1 there is a need

- For facts but no means to confirm level 1 insight, which is enough for action (episode 2).

At level 2 there is a need to

- Understand rapid development using fact recording (episode 20),
- Understand novel cues for safety and operational reasons (episode 19, 44, 50, 57),
- Integrate previous fragments of understanding (episode 21, 33),
- Request specific missing information required for operational task (episode 41).

At level 3 there is a need to

- Understand consequences of a situation for personal safety and risk reasons (episode 15, 28, 34).

At level 4 there is a need to

- Understand option because of potential dangerous consequences of an action; personal involvement, risk, crew safety (episode 1, 6).

At level 5 there is a need to

- Understand viability of an option for aversion of potential risk, personal safety (episode 32, 44).

At level 6 there is a need to

- Understand if action has desired effect for reason of personal involvement in a risky situation (episode 48, 56).

6.2.5 Mechanisms in the multiple input generation process

The purpose of this section is to report findings on the four suspected mechanisms in the multiple input generation process and present additional mechanisms. For more details on analysis see Appendix D8 as well as Appendix D9 – D12.

6.2.5.1 The usual pattern

The structure of this process variation is similar to the simple process but includes the need for creating multiple cues to make sense.
Two examples were found for moving from level 2 to level 3 and three for improving level 2 understanding.

Levels of understanding
Moving from level 2 to level 3 included episodes 27 and 39, where multiple cues are observed as facts, which are integrated to reach level 3 understanding.
Creating and up-dating the command board at the incident command post (episode 30, 53) as well as a reconnaissance tour (episode 40) were examples for reaching level 2 understanding and making multiple improvements for a more accurate understanding over time.

Sensemaking context
A sensemaking context change (to effect uncertainty) was introduced as descriptor in episodes 27 and 39, which started with the noticing of “novel cues”. The other episodes began with context “state uncertainty”, “complexity” and “information load low” and did not have any changes.

Data / goal driven sensemaking
Sensemaking in the multiple input generation process can be described as either data driven, goal driven or both.
Sensemaking was data driven in episodes 27 and 39, goal driven in episode 40 and both in episodes 30 and 53.

Cue types
No pattern was observed.

6.2.5.2 Underlying mechanisms

The question here is about the underlying mechanism that triggers the process. As the analysis in Appendix D8, D9-D12 and the description above shows there is

- Usually a move to a higher level of understanding, could be in form of improvement of the same level,
- No change in sensemaking context between stages,
- No change between data and goal driven sensemaking,
- No specific pattern in cue types as indicators.

The relevant episodes can be distinguished by two groups. Need to

- Understand operational consequences of a situation for reasons of crew safety and command post safety (episode 27, 39) – moving from level 2 to 3;
- Understand the bigger picture made up from fragmented pieces of information, need to understand the developing incident response (episode 30, 40, 53) – improving level 2.

These needs are based around situational factors, i.e.

- Crew safety,
- Operational needs and implications.

6.3 Insights and summary of findings

Seven levels of understanding were described in this chapter. The levels were related to the four sensemaking process variations that were identified earlier in chapter 5. It was shown how understanding evolves and moves across the seven levels. Underlying mechanisms were traced between process stages.

The following Figure 6-2 illustrates the combined findings from chapter 5 and 6: The figure shows that the sensemaking process and its variations are a combination of multiple process fragments. These fragments consist of the simple process as basic structure. The overall process occurs in stages. The underlying mechanisms were arranged into three groups:

- The four suspected mechanisms became the group of “cognitive factors”,
- The seven levels of understanding became the group of “needs to understand”,
- The additional factors became the group of “situational factors”.

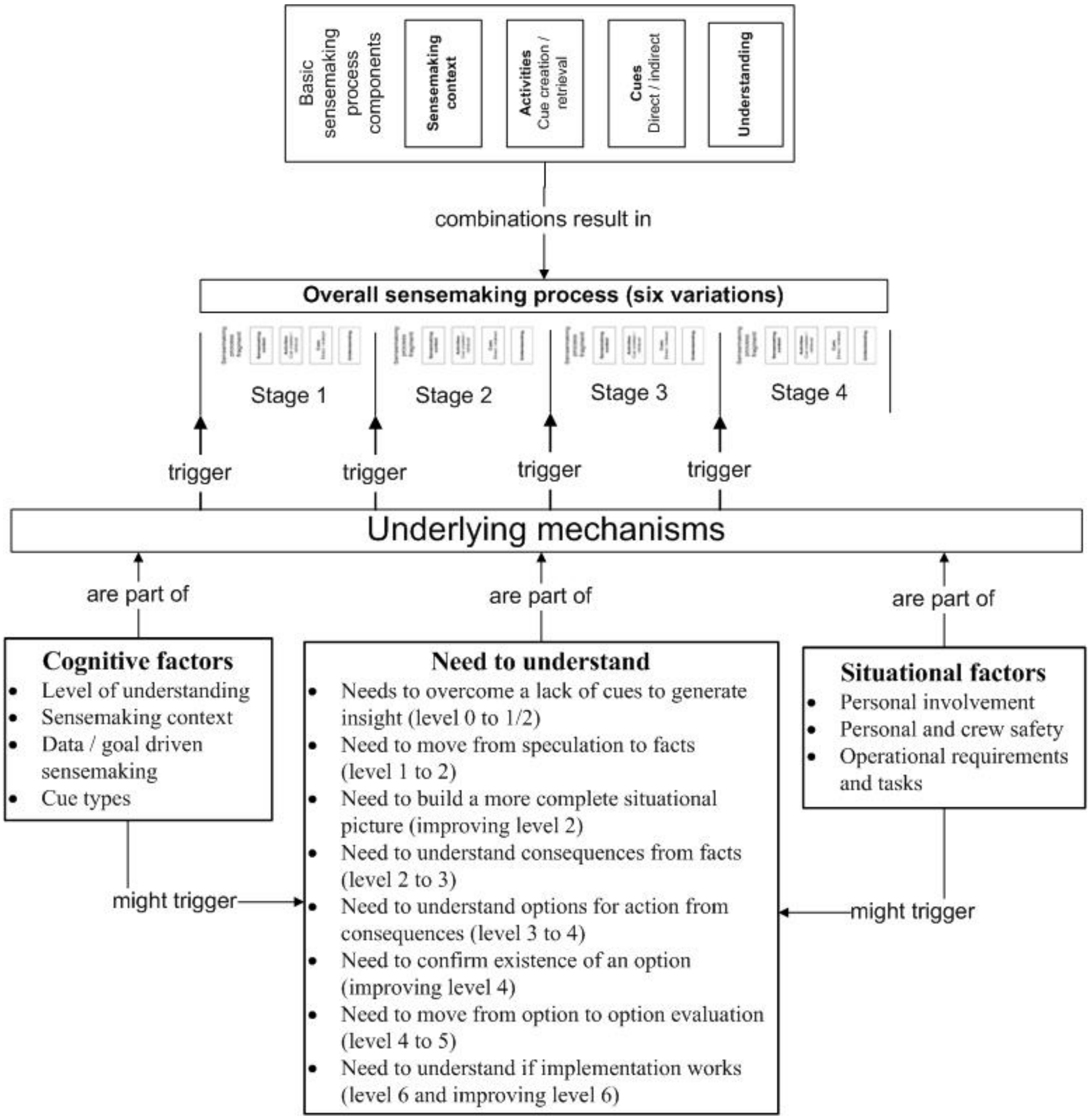


Figure 6-2 - Illustration of combined findings from chapter 5 and 6

Cognitive factors

The four suspected mechanisms were found to be at work in the emergent process variation more than in the remaining ones. Changes in the levels of understanding, i.e. moving to a higher level or improving a current level, occur at each process stage. Thus, the need to understand was identified consistently as underlying mechanism driving process structure. However, the remaining three suspected mechanisms were not consistently found. Sometimes they occur together, sometimes they do not. This was seen especially in comparison of the emergent process with the other variations. Especially in the multiple stage process, changes of sensemaking context, data/goal driven sensemaking and cue types as indicator do not seem to occur between process stages.

The need to understand

Levels of understanding were identified as underlying mechanism expressed as the

- Need to overcome a lack of cues to generate insight (level 0 to 1/2),
- Need to move from speculation to facts (level 1 to 2),
- Need to build a more complete situational picture (improving level 2),
- Need to understand consequences from facts (level 2 to 3),
- Need to understand options for action from consequences (level 3 to 4),
- Need to confirm existence of an option (improving level 4),
- Need to move from option to option evaluation (level 4 to 5),
- Need to understand if action implementation works (level 6 and improving it).

Situational factors

The current level of understanding might not be sufficient. If a situation demands to understand something specific about it, it is determined by the personal situation somebody is in. There is no indication in the data why they try to understand it. However, one needs to assume that they want or need to understand something. This drives sensemaking activities and lets individual enter processes and stages.

Thus, repeated analysis of the specific situation that individuals were in resulted in mechanisms around situational factors that trigger a specific need to make sense. These mechanisms are based around understanding driven by needs of

- Personal and crew safety,
- Operational tasks and implications,
- Personal involvement, i.e. being directly affected by a situation.

These findings were presented to experts on incident command to collect feedback. This is presented in the following chapter.

7 Expert review

The researcher presented the findings of this study to experts in incident command training from the Fire Service College. The purpose of this chapter is to convey the obtained feedback. The following sections explain

- Who the experts were and why they were chosen (see section 7.1),
- What the feedback was (see section 7.2), in terms of
- General comments (see section 7.2.1),
- If the findings reflect reality (see section 7.2.2),
- Suggestions for improvement (see section 7.2.3),
- What the findings mean in the wider incident command context (see section 7.2.5),
- The relevance of findings for command training and practice (see section 7.2.6).

7.1 Seeking experts at the Fire Service College

The Fire Service College was introduced in chapter 2. Two experts in incident command training were interviewed during a 45 minute session. Expert 1 has 25 years of experience in the UK F&R Services. In charge of the simulation suite he designs, develops and delivers incident command training for middle and senior ranking officers in the UK and abroad for international F&R Services. Previously he was Incident Command Development Officer and holds a degree in Integrated Emergency Management.

Expert 2 has 34 years of experience. He served 32 years in the UK police force where he held the rank of Chief Superintendent, acted as incident commander of several large scale incidents involving multiple agencies and received the Queen’s Police Medal (QPM) for distinguished service. For the last 2 years he has been lecturer and associate tutor in incident command at the Fire Service College. He delivers incident command training for middle and senior ranking officers, especially on multiagency operations.

The choice of experts was deliberate. The option to interview senior officers of regional F&R Services was ruled out for reasons of more comprehensive expertise at the Fire Service College. Specifically, the chosen experts have

- Academic as well as practitioner background,
- Knowledge and theoretical background on decision making, situation awareness and risk assessment during incidents,
- Practical, first-hand experience as acting incident commanders,
- Observed and assessed hundreds of participants on their incident command performance during simulations,
- Knowledge of incident command in the Fire Services as well as police force,
- Knowledge of the wider context of incident command and emergency management.

The aim was to focus on the theory building part of the research, i.e. sensemaking occurs in stages, which lead through 7 levels of understanding, which have three groups of underlying mechanisms (see chapter 6). The researcher first explained the research topic and findings and then asked the experts for their comments. The presented material and question guideline can be found in Appendix E1 and E2. The feedback session took the format of a guided discussion rather than an interview to allow diversity of comments.

7.2 The experts' comments

The purpose of this section is to present experts' comments on the findings. The section is organised by comments in general, relation to reality, improvements, differences to and impact on training practice as well as wider context.

7.2.1 General comments on the levels of understanding and underlying mechanisms

Both experts agreed that the levels and underlying mechanisms are logically structured, make sense and that practical terminology was used. They referred to the levels and underlying mechanism as framework that captivates the reader by its simplicity while reflecting the practice of exercising command. Seeing the framework immediately allowed them to come up with examples from their own experience, illustrating how an individual tries to build and improve understanding while going through the seven levels. In their opinion the framework was credible because it originated from data on an actual incident. Most importantly, from their experience as practitioners they thought that the elements in the three groups of underlying mechanisms really trigger attempts to make sense, i.e. sensemaking process stages.

They commented that from a cognitive/psychological point of view a situation always starts with level 0 understanding. If an individual adopts a number of or all phases depends on the person as well as the situational circumstance. This confirms the finding that people might not go or have to go through all stages. Level 4-5 resemble a decision making process but all decisions made on scene go through at least some of the stages. The cycle might be very quick (e.g. 10 seconds) or last longer (e.g. 20 minutes), depending on the situation and task. This confirms the finding that the seven levels are applicable in processes of short or long duration.

7.2.2 Degree to which findings reflect reality

In the experts' opinion the framework adequately reflects the thinking that an incident commander goes through in a situation. The experts could picture themselves being at a large scale incident going through the stages, which means that practice is reflected in the framework. Moreover, teaching on incident command fits in all seven levels. The experts could see how exercise participants move through all framework levels in a scenario. They provided an example based on a scenario that is used at the college to train incident command.

These comments contribute to internal validity of research results.

The comments in the previous and this section confirm that the sensemaking process progresses in stages, tied to levels of understanding. Moreover, the feedback conveys confidence in the correctness of the theory-building part of the research, i.e. that the identified levels of understanding and underlying mechanisms exist, reflect practice, and trigger process stages. This suggests that the findings answer the research questions.

7.2.3 Suggestions for improvement

Although the experts found no conflict in the framework there were some suggestions for improvement. They commented that the characteristics of all levels need to include potentiality. So far, this is only reflected in form of level 1 (what might happen) but also in form of examples on level 3 (potential consequences) and 4 (potential option). However, this comment confirms that there are degrees of understanding within a level, e.g. improving understanding by moving from a potential to a confirmed consequence.

The experts commented that in practice some levels might progress fast (e.g. 4-5), some slow (level 2) and some might not feature much (level 6). Information quality significantly influences understanding of a situation, which means that in large incidents that take several days a cycle or single stage spans the same period. Therefore, duration might be an additional element to be considered in the framework.

The experts often referred to the seven levels as a cycle, which contrasts its current illustration as a hierarchy. They commented that especially level 6 (performance evaluation) relates back to level 2 (what is happening). In practice one would see many jumps and up-dates between levels as a situation progresses. This is currently not reflected in the framework. Moreover, they said that to gain the overall understanding of an incident (which might last several days), one goes through multiple cycles of the seven levels. This means there are multiple sub-cycles depending on the current tasks and situation development. Consequently, there should be an overall cycle that consists of and is informed by sub-cycles. This suggested a nested structure of the process to understand and introduces the idea of long-term, overall cycles and short-term cycles.

7.2.4 Differences to what is taught on incident command at the Fire Service College

The Fire and Rescue Manual on incident command (HM Government, 2008) includes a decision making model developed by practitioners of the London Fire Brigade. It is used and taught at the Fire Service College and comprises the stages of: collect and think about information (on incident, resources, hazard and safety), prioritise objectives, plan, communicate and control, evaluate outcome (which links back to think). The experts commented that the model reflects the seven levels of understanding. Moreover, the levels provide a micro-lens on what is going on within the elements of the decision making model.

7.2.5 Findings in the wider context of incident command

The experts commented that in recent years the importance of establishing accountability for all actions and decisions taken during an incident has increased. Therefore, logs and notes are kept for reasons of justification. The research findings are important because they could provide a framework to lead through formal accountability. Courts and the public will not accept diluted answers but want to see that a structured approach was followed that they can also understand. If evidence has to be provided in court, then this has to be structured to demonstrate the process a commander went through. The findings offer a framework that structures the content of evidence provision. The recency of findings and event used for the research modernise the thinking which becomes important in terms of accountability.

The findings seem to be applicable in the context of criminal investigation and incident management in the police force. Using the example of the recent Cumbria shootings one expert commented that he can see how the levels of understanding apply to this context. In this tragic event a man drove across several towns in Cumbria shooting people in the street in an apparently random manner. The current findings apply in this context as follows:

- Level 0 – report of someone being shot
- Level 1 – might be a hunter shooting rabbits
- Level 2 – report on a body being found
- Level 1 – first hypothesis of what might have happened
- Level 2 – new evidence of more bodies
- Level 3 – evidence might mean that this event carries on
- ….

In the early stages, when the police tries to understand what is going on there are a lot of uncertainties. The expert commented that in this context the levels resemble dynamic hypothesis testing, which is used in police training.

The feedback on the wider applicability of the findings contributes to external validity of this study.

7.2.6 What the findings mean for incident command training

One comment was that the levels of understanding and cognitive factors as underlying mechanism reinforce the value of incident command exercises. Exercises are designed to challenge thinking skills by confronting participants

- with uncertain and ambiguous situations (sensemaking context),
- with novel data which they need to understand (data driven sensemaking) but also move on to determine consequences for operations or courses of action (goal driven sensemaking),
- with information of unclear quality so they question their current understanding (level of understanding, unsatisfactory cue type).

The finding of cognitive factors as underlying mechanism to develop understanding means that training focuses on the right aspects.

The research findings help to understand the process that people will find themselves in when they are thrown in an unknown situation. It can make exercise participants aware of the thinking stages they are likely to go through during incident response. This includes novel and familiar situations. The findings provide a framework to approach a crisis. They help to reflect or raise awareness when making decisions, e.g. if understanding is at factual level or still an assumption at level 1. If people know about the stages they are likely to go through, they might be able to move forward more quickly. What is required is a level of acceptance from commanders if they cannot move to a higher level but also a give them confidence if they can become aware that they cannot improve a level.

The framework was seen important from a training perspective because it is an easy way to explain what happens on a cognitive level during incident command. This is mostly relevant in courses on incident command basics.

Building on the work of Weick (2002) the researcher suggested that the seven levels might be converted into a communication protocol for briefings: Here is what might be going on – here is what actually happens – these are potential/immediate consequences – here are (potential) options – here is how we are doing. The experts commented that this would help primarily to communicate understanding and allow the commander to test his own perception against that of others. It could help to raise awareness of poorly understood areas, e.g. I don't understand enough about consequences, and therefore I need to bring in a specialist who can provide it.

The experts suggested that the findings could be relevant for the work of command support units. These units use a lot of displays to document the overall progress and vital information on the incident. Two mnemonics are used as aid to structure the response organisation: SWIMMERRS and CHALET. A matrix might be used to match these against the seven levels of understanding. This is illustrated in Table 7-1 below.

SWIMMERRS	**CHALET**	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
Safety	**C**asualties			120 badly injured	need to be moved to hospital	hospitals that can be used are....		35 trans-ported so far
Welfare	**H**azard							
Incident, command, tactics	**A**ccess							
Multiagency	**L**ocation							
Media	**E**mergency							
Environment	**T**ype							
Resilience								
Reputation								
Strategy								

Table 7-1 - Potential use of findings in command support

The matrix might help to visualise what is understood about the incident, visualise progress as well as what is not yet understood. This could be useful to support situation awareness.

The feedback in this section contributes to demonstrate the potential application value of findings.

7.3 Chapter summary

This chapter presented feedback on study findings, obtained from experts at the Fire Service College. The feedback on the findings was positive. The levels of understanding and underlying mechanisms reflect incident command practice, have implications for the wider command context and potential applications in training. It was argued that the experts' comments add to demonstrate internal and external validity as well as applicability of findings. Moreover, the feedback suggests that the findings answer the research questions.

8 Discussion of findings

In this chapter the findings of this study will be discussed. The chapter comprises

- A summary of findings from chapter 5 and 6 (see 8.1),
- Discussion of the sensemaking process from a holistic point of view (see 8.2) as well as its structure in comparison to literature (see 8.3),
- Discussion of underlying mechanisms, divided into three groups: cognitive factors (see 8.4.1), the need to understand (see 8.4.2) and situational factors (see 8.4.3),
- Discussion of evolving understanding (see 8.5),
- Discussion of findings in the wider context of sensemaking research (see 8.6.1) as well as incident management (see 8.6.2), followed by
- The researcher's own view of sensemaking and learning (see 8.7),
- Reflection on methodology as well as strengths and limitations of the research (see 8.8), before the chapter concludes with
- Potential use of findings in research practice (see 8.10.1) and emergency responder training (see 8.10.2).

8.1 Summary of findings

The purpose of this section is to summarise the overall findings before they are discussed. It is important to present the findings in one place because the discussion on the significance of results requires combining answers to RQ1 and RQ2.

Regarding RQ1 it was found that to make sense of events during an emergency individuals follow a process that

- Has at least six structural variations resulting from combining the basic structure in different ways
    - Basic process sequence (simple process),
    - Dealing with limitations of understanding (emergent process),
    - Taking understanding further (multiple stage process),
    - Considering many aspects of a situation (multiple input and multiple gap process),
    - Dealing with new challenges as consequences of gained understanding (gap-triggers-gap process),
- Has at least one stage,
- Is characterised by (interim) understanding at each stage,
- Can be fragmented, i.e. the complete process might consist of a combination of identified process variations.

Regarding RQ2 the following mechanisms were found to explain why process stages occur:

- Each stage in the process has a purpose and results in an (interim) output, described in seven hierarchical levels of understanding; i.e. understanding
    - That something is happening (level 0),
    - What might be happening (level 1),
    - What is happening (level 2),
    - Consequences (Level 3),
    - Option generation (Level 4),
    - Option evaluation (Level 5),
    - Performance evaluation (Level 6),
- Three groups of mechanisms were identified that can explain why a process stage is triggered
    - Cognitive factors
        - Current level of understanding,
        - Change or no change in sensemaking context,
        - Change between data and goal driven sensemaking,
        - Characteristics of cues (descriptive cue types, e.g. non-definitive cue)
    - Need to understand
        - Need to overcome a lack of cues to generate insight,
        - Need to move from speculation to facts,
        - Need to build a more complete situational picture,
        - Need to understand consequences from facts,
        - Need to understand options for action from consequences,
        - Need to confirm existence of an option,
        - Need to move from option to option evaluation,
        - Need to understand if action implementation works,
    - Situational factors
        - Personal involvement in a situation,
        - Personal and crew safety,
        - Operational task requirements,
- Not every mechanism is observed at every stage, meaning that a focus on a single mechanism is an insufficient explanatory factor for process stages.

The findings were combined and illustrated in Figure 6-2 at the end of chapter 6.

8.2 Taking a holistic view of the sensemaking process

The purpose of this section is to justify the process view of sensemaking, compare it to previous research and highlight the contributions of this study. The section is summarised in the following Table 8-1.

The new knowledge… By taking a holistic view of the sensemaking process and adopting a formalised process structure (basic structure: trigger, activities, input, output) new insights could be gained on the role of sensemaking context and understanding, traditionally shown only as trigger and output of the overall process. Sensemaking context can change during the process and is a trigger of process stages. Understanding is gained at each process stage and evolves throughout the process.
Based on… • Literature review on process structure and elements (chapter 3, part 1 and 2) • Results on process structure (chapter 5) • Results on understanding as process output, hierarchy of seven levels of understanding (chapter 6, part 1 and 2) • Results on tracing underlying mechanisms through process stages (chapter 6, part 2)
Similar to… • Process view of sensemaking but with focus on specific process elements (e.g. Hutton et al., 2008; Ntuen, 2008; Jensen and Brehmer, 2005) • Sensemaking context as process trigger (e.g. Klein et al., 2007a; Weick, 1995) • Learning loop complex (e.g. Russell et al., 1993; Qu and Furnas, 2005)
Different with regard to… • Use of formalised process structure • Holistic process view, including trigger, activities, input and output • Traces sensemaking context and understanding throughout the process • Includes understanding as (interim) output and provides detail on its characteristics

Table 8-1 - Discussion summary for holistic process view

The majority of definitions provided in chapter 3.1.2 characterise sensemaking as a process. A process to search and build information representations (Russell et al., 1993), fuse information to gain understanding (Ntuen, 2008), to build situation awareness (Hutton et al., 2008), gain situational understanding (Jensen and Brehmer, 2005), figure out how to act (Ntuen and Leedom, 2007). Even definitions that do not mention a process view explicitly leave no doubt that the way to make sense is a process.

Although the process view seems to be a common perspective in sensemaking research, no studies could be identified that used a formalised process structure like in the present investigation. If a process view was to be used the researcher found it necessary to include the typical elements, i.e. trigger, activities, input and output. Only this approach would ensure that the entire process from beginning to end would be covered. One reason why other authors have not covered the complete process might be that they were only interested in single aspects, e.g. activities (Sieck et al., 2007), communication (Landgren and Nulden, 2007; Landgren, 2005), specific tasks (Dyrks et al., 2008; Denef et al., 2008) or information flows (Toups and Kerne, 2007).

Many authors agree that the process is triggered by what is called in this research a sensemaking context, e.g. ambiguity, surprise, uncertainty (Klein et al., 2007a; e.g. Weick, 1995). However, current literature seems to take it for granted that once the context is resolved, sensemaking stops. They do not report what triggered the episodes they studied. No literature could be identified that attempted to track how sensemaking context develops along the process. The present findings suggest that consistently showing sensemaking context can help to understand why sensemaking was required in the first place. While confirming that sensemaking context is a process trigger, this study advances previous findings by showing that it can change between process stages. Thus, it becomes important to trace sensemaking context as one explanatory factor for process stages.

Although many of the provided definitions in chapter 3.1.2 make a reference to understanding as output of the sensemaking process, it has not been the focus of past research. However, this research extends previous studies by including understanding as process output. It was shown that sensemaking is a process in which understanding evolves along seven hierarchical levels. Thus, this study also provides a more detailed characterisation of sensemaking process output than previous studies. Moreover, findings suggested that the overall process can be characterised by several stages, each of which has understanding as an interim output. Although previous studies have suggested that understanding improves in repeated sensemaking cycles, e.g. learning loop complex (Russell et al., 1993; Qu and Furnas, 2005), the present study adds more detail by showing through which specific levels understanding can evolve. This means that understanding is not only an end product but also an interim product.

8.3 Discussion of process structure

The purpose of this section is to compare findings on process structure to previous research and highlight the contributions of this study. The section is summarised in the following Table 8-2.

The new knowledge… The sensemaking process consists of at least one stage that follows a basic structure. The basic structure and identified variations offer a detailed view, demonstrating that the purpose of a process stage can be to address limited understanding, taking it to a higher level, multiple gaps or situation aspects. This offers a micro-level view of more high-level activities shown in existing sensemaking process models, e.g. elaborating frames. Process stages are tied to gaining understanding, expressed here in form of seven levels.
Based on… • Literature review on sensemaking process models (chapter 3, part 1 and 2) • Results on process structure and variations (chapter 5) • Results on purpose of process stages and linking understanding to them (chapter 5 and 6)
Similar to… • Activities in Data/Frame Theory (Klein et al., 2007a; Sieck et al., 2007) • Activities in information processing and analysis process models (e.g. Russell et al., 1993; Ntuen, 2008; Pirolli and Card, 2005)
Different with regard to… • Not concerned with building external representation structures, cognitive frames, large amounts of data • Firmly situated in emergency setting • Process stages can be distinguished explicitly by combining them with purpose, e.g. addressing limitations, take understanding further, multiple gaps, multiple aspects of a situation • Provides higher level of detail for what could be interpreted as process stage in other models, e.g. what happens while elaborating a frame • Showing a nested structure of the sensemaking process, using process variations instead of a single model • Linking process stages to how understanding evolves

Table 8-2 - Discussion summary on process structure

The general idea that the structure of the sensemaking process is one that involves stages is not new. The various sensemaking process models described in chapter 3 can be interpreted to consist of distinct stages. The central focus of the process models from the information domain (Russell et al., 1993; Ntuen, 2008; Pirolli and Card, 2005) and the Data/Frame Theory (Klein et al., 2007a; Sieck et al., 2007) is either on external representation or on cognitive frames to make sense. Despite this contrast to the present study, which is on building and improving understanding, they are closely related and will therefore be considered in the discussion.

Although not explicitly mentioned to comprise of stages, the Data/Frame Theory (Klein et al., 2007a; Sieck et al., 2007) could be interpreted as such. As the seven sensemaking activities influence frames to explain events, the occurrence of each activity could be interpreted as a process stage. Four of the activities were also found in the present study: connecting data and frame (new cues are understood by connecting them to a previous experience), elaborating a frame (improvement of understanding by moving from level 1 to 2 or improving level 2), questioning a frame (new cues do not correspond with previous explanation) and comparing multiple frames (where several possible explanations are found). However, based on the examples the above mentioned authors use in their book chapter to illustrate the sensemaking activities, each activity can be a lengthy process itself. For instance, elaborating a frame, i.e. adding more detail to an existing explanation, can involve several searching and observation activities to produce several new cues, where each one might improve the frame. The current findings suggest that improving explanations (elaborating a frame) can involve several process stages, which might follow any of the process variations shown in chapter 5.
Moreover, by using the process variations of this research it would be possible to show: if a single activity, e.g. elaborating a frame, consist of only one process stage (simple process); if limitations of understanding happen and are addressed (emergent process); if elaborating a frame requires multiple inputs (multiple input process); if an already elaborated frame is further improved and what understanding is gained (multiple stage process); if the task does comprise several sub-gaps which might require multiple frames for explanation (multiple gap process).
Thus, the current study advances the Data/Frame Theory by adding another layer of detail. This means that the current findings would allow for an explanation what happens within a single sensemaking activity, e.g. elaborating a frame. The interview with experts also showed that the current study offers a micro level view on stages within the decision making model of Fire & Rescue Services (see chapter 7).

Contrary to the Data/Frame Theory, the current findings can explain what process people might follow if they encounter problems in elaborating the frame. In the Data/Frame Theory one would move to another activity, i.e. questioning the frame. It is not disputed that this does not happen but the researcher suggests that this activity actually takes place within the frame elaboration activity. This would suggest a nested structure of the sensemaking process, where a general sensemaking process consists of smaller structures. Using the findings of this research, a combination of several process variations would allow accounting for and showing this nested structure. For this reason, it is suggested that the current findings advance previous research by offering a flexible modelling approach that allows showing more detail in process stages.

It was identified that a single gap can consist of several sub-gaps. This was the case where understanding the bigger picture of the incident a commander needs to understand e.g. incident scale, risks and resources. In the Data/Frame Theory it is argued that people might develop competing frames in parallel, e.g. following two possible explanations for an event. The theory is advanced by current findings because people do not only pursue competing frames in parallel but also complimentary ones, which are later combined into a bigger picture.

Although the Data/Frame Theory shows how people create, elaborate, preserve or alter frames it does not show if and how a changed frame leads to improved understanding. For instance, an elaborated frame might just improve understanding of what is currently happening but not what the consequences of the situation are. The findings advance previous research by linking every process stage to a level of understanding and, thus, show if and how understanding develops.

The process models originating from the information processing and analysis domain show a few fundamental differences to the current study. First, the context of these studies is not an emergency setting and does not show the features of a naturalistic environment (Orasanu and Connolly, 1993) mentioned in chapter 1. Second, in the episodes of the current study people were not confronted with large amounts of data. Third, with only few exceptions people use internal (cognitive) processes, whereas the focus of the information domain is largely on creating and improving external representations. Fourth, the current study focuses on understanding, whereas improved representation structures and reports as process output are the focus of information processing and analysis studies. Contrary to the studies in these domains the findings suggest that in an emergency situation people might not focus on building a good structure to explain information. They might not have the time or means to it. The focus is rather on understanding here and now what is going on and what can be done, without the help of external representations. This does not mean that external representations are not used in an emergency context. At the command post of a fire incident or in the command centre of a general emergency, extensive use of external representations is made (Jiang et al., 2004; Jenkins et al., 2010). However, these were not the focus of this study.
Because of the fundamental difference in the domain context and the focus of process models on building information representation structures, they do not seem to be useful to explain sensemaking in the context of the current study. However, it might be possible to apply the current findings in the information processing and analysis domain. This would mean to adopt the perspective of how understanding develops in the process stages to build representations, which seems to be less of a leap than the other way round.

8.4 Underlying mechanisms of sensemaking process stages

The purpose of this section is to compare findings on underlying mechanisms or triggers for process stages to previous research and highlight the contributions of this study.

8.4.1 Cognitive factors

The cognitive factors comprise level of understanding, sensemaking context, data/goal driven sensemaking and cue types. The section is summarised in the following Table 8-3.

The new knowledge… This research identified four cognitive factors as underlying mechanisms of process stages: change in sensemaking context, change between data- and goal-driven sensemaking, two descriptive cue types (non-definitive and unsatisfactory cue) as well as insufficient level of understanding. However, they are not consistent explanatory factors because they tend to occur in different combinations and they are not found in every process variation.
Based on… • Observed changes in sensemaking context, especially the emergent process variation (chapter 5 and 6) • Finding of performance uncertainty as sensemaking context in action stage (chapter 5 and 6) • Analysis process stages with regard to four potential mechanisms (chapter 6)
Similar to… • Sensemaking context as general process trigger • Inconsistent or novel data, anomalies, surprise in the Data/Frame Theory • Data residue in information representation structure (Russell et al., 1993) • Data/goal driven process parts (Pirolli and Card, 2005)
Different with regard to… • Sensemaking context not only as general process trigger but also of interim stages • Addition of performance uncertainty as sensemaking context • Only goal driven sensemaking is possible, a switch might not happen • Use of descriptive cue types to characterise process elements • Sensemaking context, data/goal driven sensemaking and cue types are not consistent explanatory mechanisms, i.e. might not occur in e.g. the multiple stage process variation • Addition of perceived insufficient level of understanding (wanting to understand) as mechanism

Table 8-3 - Discussion summary on cognitive factors as underlying process mechanism

Previous research has found that sensemaking happens when something stops us from understanding and acting (Dervin, 1983), current understanding is doubted (Weick et al., 2005), in case of ambiguity, uncertainty, complexity, turbulence (Weick, 1995), too much or too little information (Huber and Daft, 1987; Cited in: Weick, 1995).

These studies have mentioned sensemaking context as process trigger but not described it as mechanism at interim process stages. Klein et al. (2007a) provided more detail and listed a number of triggers at interim process stages: inconsistent or new data, anomalies, problem detection, surprise, emotional factors like perceiving uncertainty or distress, competing and inadequate frames. Russell et al. (1993) mentioned residue, i.e. data that does not fit a created representation structure, as reason for entering another sensemaking cycle.
Whilst not disagreeing with these previous studies, this research found that in the emergent process variation a change of sensemaking context can occur (see chapter 6). Thus, this research has extended the list of triggers for interim process stages provided and shown that sensemaking context is not only a trigger of the very beginning of the sensemaking process. Another finding was a previously not mentioned sensemaking context: performance uncertainty (see chapter 6). Thus, sensemaking does not only prepare and result in action, it might continue while acting.

Pirolli and Card (2005) distinguished between data and goal driven sensemaking. This means that a change between them indicates a new stage by launching new activities, e.g. new data was explained using a hypothesis (data driven) and the actor might want to confirm it (goal driven). The findings confirm the previous study. It was found that in the emergent process a change in sensemaking context happens at the same time as a switch from data to goal driven sensemaking. The goal is e.g. to confirm, test, explain or collect new data. However, several entirely goal driven episodes were found. This was the case when a lack of data exists. Pirolli and Card's process model cannot account for this instance because it always starts with data that needs to be explained. In the context of information analysis this view is logical. However, in the context of this study a refined view is necessary.

A number of descriptive cue types were used to characterise insights at each process stage. This approach was useful to understand the structure of the process better by introducing an abstract high level view of cues and insights. Two cue types, i.e. "unsatisfactory" and "non-definitive", were especially found at the interim process stage in the emergent process and before action was taken. As these descriptors were created by the researcher it cannot be claimed that these are real triggers of process stages. For instance, it was inferred that individuals who created a hypothesis for an event and then seek confirmation would perceive the hypothesis as non-definitive insight. However, for the emergent process the cue types worked well as potential trigger for another stage. Moreover, characterising process parts helped to find differences between process variations and supported the development of levels of understanding through constant comparison.

It was found that sensemaking context as well as a change between data and goal driven sensemaking are process stage triggers. However, they are not a consistent explanatory mechanism. In the multiple stage process they were not found between stages, nor were the cue types helpful to indicate a new stage. This is an important finding because it has implications for research that seeks to test rather than build theory. In line with the social realist paradigm and retroductive research strategy the finding demonstrates that it is likely that there is a multitude of mechanisms causing a phenomenon. However, not all of them are active at the same time or they might cancel each other out. If one was to test one or two mechanisms, then other possible mechanisms are likely to be disregarded or not even looked for. However, other mechanisms should be considered because the findings suggest that one or two specific mechanisms work in one circumstance but do not explain the same phenomenon in other circumstances.

Thus, it is suggested here that other mechanisms are at work in the multiple stage process. These are the current level of understanding, the need to understand as well as situational factors.

The current level of understanding might be perceived as insufficient but there is no direct need to understand it. However, people try to build and improve understanding. This is evidenced in a number of episodes; For instance, hearing a plane flying very low over Manhattan without seeing it, followed by the sound of impact. There seems to be no direct situational or operational need to understand this event but people try to make sense of it anyway. In terms of the described hierarchy of understanding (see chapter 6) the above described episodes included unsuccessful attempts to move to a higher level of understanding, followed by repeated attempts. This is seen as evidence that people want to understand. It cannot be judged here if people are consciously aware that their current level of understanding is insufficient. However, based on the above described episodes it is suggested that the current level of understanding might be perceived as insufficient by an individual and thus triggers stages in the sensemaking process. This view was also shared by the experts who were interviewed for feedback (see chapter 7).

8.4.2 Need to understand

The purpose of this section is to compare findings on the need to understand as underlying mechanism to previous research and highlight the contributions of this study. The section is summarised in the following Table 8-4.

The new knowledge… Understanding is gained at each process stage. Seven levels of understanding were found that can be expressed as eight needs to understand. This provides a more detailed view of what specifically fire crews and incident commanders try to understand than current literature.
Based on… • Literature review: purpose of sensemaking, firefighter and command sensemaking (chapter 3) • Results on understanding as (interim) process output (chapter 6) • Results of tracing understanding through the sensemaking process (chapter 6)
Similar to… • General need to understand a situation (Hutton et al., 2008; Klein et al., 2006a) • Description of what generally needs to be understood in form of high level operational tasks (e.g. Jiang et al., 2004; Toups and Kerne, 2007)
Different with regard to… • Providing detail as to what might need to be understood within operational tasks • Description of what form this understanding takes • Distinguishing between seven levels of understanding, including characteristics and activities to gain it • Translating the seven levels into eight needs to understand

Table 8-4 - Discussion summary on need to understand as underlying process mechanism

The need to understand a situation has been described in the literature (Hutton et al., 2008; e.g. Klein et al., 2006a). However, the literature review identified a lack of research on what is actually understood at interim stages and the end of the sensemaking process.
The present study fills this gap in literature with the seven level hierarchy of understanding (see chapter 6). The study provides new insight into what people try to understand as well as how understanding develops along the sensemaking process. By investigating what is understood in each process stage, it was possible to translate the seven levels into eight "needs to understand", as presented in chapter 6:

- Need to overcome a lack of cues to generate insight (level 0 to 1/2)
- Need to move from speculation to facts (level 1 to 2)
- Need to build a more complete situational picture (improving level 2)
- Need to understand consequences from facts (level 2 to 3)
- Need to understand options for action from consequences (level 3 to 4)
- Need to confirm existence of an option (improving level 4)
- Need to move from option to option evaluation (level 4 to 5)
- Need to understand if action implementation works (level 6 and improving level 6)

Previous research has described what fire crews and incident commanders need to understand: the incident and its status (Jiang et al., 2004), location and nature of the incident (Landgren, 2005), navigation under low-visibility (2008), resource locations, assignments, progress and risks on site (Jiang et al., 2004; Toups and Kerne, 2007). These are general descriptions of typical operational tasks. However, the findings advance existing literature by explaining what individuals might need to understand within one of the above listed tasks, e.g. nature of the incident or its status.
The need to understand might be influenced by situational factors, which are described in the following section.

8.4.3 Situational factors

The purpose of this section is to compare findings on situational factors as underlying mechanism to previous research and highlight the contributions of this study. The section is summarised in the following Table 8-5.

The new knowledge… The nature of operational tasks, personal and crew safety as well as personal involvement in a situation are triggers of the sensemaking process in general as well as its stages.
Based on… • Analysis of process stages with regard to alternative mechanisms, driven by other inconsistent explanatory mechanisms (chapter 6)
Similar to… • Operational tasks require sensemaking (e.g. Dyrks et al., 2008; Landgren, 2005) • Safety requirements of fire fighting work, risk assessment (HM Government, 2008; Jiang et al., 2004)
Different with regard to… • Linking operational tasks, safety and personal involvement as complementary mechanisms to process stages

Table 8-5 - Discussion summary on situational factors as underlying process mechanism

In the previous section several operational tasks were mentioned. The nature of the work automatically requires sensemaking. For instance, the incident commander needs to ensure that the command post is set up at a safe location, tracking resources and progress of incident response is a typical operational requirement (Jiang et al., 2004). Landgren (2005) showed that trying to understand where an incident takes place precedes understanding what exactly the incident is about. This is not only an operational task but supports the finding of multiple stage sensemaking, i.e. understanding where and, by building on this insight, understanding what.
Personal and crew safety are of paramount concern in the fire services. (Dynamic) risk assessments take place continuously to ensure operational and crew safety (HM Government, 2008; Jiang et al., 2004). Thus, trying to make sense of risk for safety reasons, e.g. building structure, fire, hazardous areas and materials, is a typical task. As many episodes have shown, especially the ones when towers collapse and being in the dust cloud afterwards, making sense of what is going on, consequences and options for

action is crucial because it might be life saving. The specific levels of understanding might be influenced by and reflect the natural risk assessment behaviour of fire crews.
The findings also describe personal involvement as a mechanism. Although there is no direct proof that this triggers sensemaking, there are strong arguments in favour. Personal involvement is interpreted here as being directly affected by what is happening. It is suggested that standing near a collapsing building is likely not only to trigger sensemaking on what is going on but also on whether one is affected by it (consequences) and if so what should be done. This would mean to move between several levels of understanding (e.g. level 2-5) and qualify personal involvement as mechanism for continuing through several process stages. In contrast, a person watching the building collapse on TV is not directly involved in this situation. The person is not forced by the situation to make sense of consequences or what should be done.
It is suggested that these situational factors link back to the previously described needs to understand. This view was also shared by the experts who were interviewed for feedback (see chapter 7).

8.5 Discussion of evolving understanding

The purpose of this section is to compare findings on the seven level hierarchy of understanding to previous research and highlight the contributions of this study. This includes discussion of evolving understanding. The section is summarised in the following Table 8-6.

The new knowledge… In the context of this study it was found that the stages of the sensemaking process result in situational understanding that takes the form of a seven level hierarchy, which is structured from the general to the specific. This extends the current view of sensemaking in form of understanding what is going on and what can be done to include understanding performance of doing something. Understanding develops across the seven levels in six different ways, showing how it evolves along the process.
Based on… • Literature review on understanding (chapter 3, part 2) • Results on understanding as (interim) process output (chapter 6) • Results of tracing understanding through the sensemaking process (chapter 6)
Similar to… • Developing larger sense from smaller cues (Weick, 1995) • Elaboration activity in Data/Frame Theory (Klein et al., 2007a) • Learning loop complex (Russell et al., 1993) • Evolving understanding of an entire incident (Landgren, 2006) • Three stages in the situation awareness model (Endsley, 1995a; 2000) • Six cognitive categories in Bloom's revised taxonomy of learning objectives (Bloom, 1956; Krathwohl, 2002)
Different with regard to… • Focused on situational understanding in emergency response • Not concerned with understanding of an entire incident but smaller episodes within • Not concerned with correct situational understanding • What specific understanding is gained (seven level hierarchy) • Sensemaking episodes might include only one level of understanding or span across several levels • Extends previous view of sensemaking from "what is going on" and "what can be done" by including action phase: "performance of doing something" • Levels of understanding work from general to specific not the other way round • Showing six ways/directions in which understanding might evolve, including how understanding can drop to a lower level

Table 8-6 – Discussion summary of findings on understanding

The idea that sensemaking is a process that evolves understanding is not new. However, the literature review identified a lack of research on understanding at interim stages and as outcome of the sensemaking process.
The finding of the seven level hierarchy of understanding (see chapter 6) fills the previously described gap in literature (see gap 4 in chapter 3). By linking it to process

stages it could be shown what understanding is gained at each level and how it evolves throughout the process. To the best of the researcher's knowledge there are no sensemaking studies that cover this aspect. Thus, the finding advances knowledge by characterising the (interim) output of the sensemaking process and demonstrating how understanding evolves.
The seven levels can be summarised as follows:

- Understanding what is going on (levels 0-3)
- Understanding what can be done (level 4-5)
- Understanding performance of doing something (level 6).

Weick (1995) described sensemaking as developing a larger sense from small cues and distinguished two stages, i.e. "what's the story here" and "what can we do about it"? As new cues become available the sense is up-dated and improved. The elaboration activity in the Data/Frame Theory (Klein et al., 2007a) leads to improved situational understanding. The theory also asserts that people might try to gain two types of understanding, i.e. situational (what is happening) and functional (what can be done). These studies support the current findings. However, the current research expands the findings from literature by adding a third stage, i.e. performance of doing something. The findings suggest that sensemaking studies should extend their current perspective to include action that is based on previous insights. This study goes beyond the suggestions of literature that sensemaking serves to prepare action and decisions. It was shown that individuals try to make sense of their action in terms of whether it has the desired effect.
The expert review confirmed the view of evolving understanding across the seven levels (see chapter 7).

The literature on sensemaking in fire fighting suggested the overall incident is understood better over time and that dynamic situation and requires constant information up-dates (Dyrks et al., 2008; Landgren, 2006). The current study moved the perspective of sensemaking from the overall incident to a deeper level of detail by investigating how understanding develops while facing (sudden) specific situation developments.

Three levels of understanding can be distinguished in Endsley's (1995a; 2000) situation awareness model and six levels in Bloom's revised taxonomy of learning objectives (Bloom, 1956; Krathwohl, 2002).
The situation awareness model comprises the stages of perception, comprehension and projection. The current findings differ in a number of ways. First, it was shown that perception of cues (level 0 – understanding that something is going on) can lead to immediate action without an attempt to understand more about what is going on. Second, Endsley's model focuses on determining if someone develops a complete and correct picture of a situation. The current levels of understanding are not concerned with correct understanding. Third, the situation awareness model stops short of taking action, whereas this is integrated in the current study.
Bloom's taxonomy works from the specific to general. The lower categories are about remembering specific facts and create meaning about them, whereas the highest level of understanding is expressed in applying a concept to new contexts. In contrast to Bloom's taxonomy, the findings suggest that understanding events works from the

general to the specific, i.e. something is happening → one or several possibilities of what is happening are narrowed down to what is actually happening → for this specific situation it is figured out what can be done (which might include narrowing down from several possibilities) → leading to acting in a specific way.

The finding on the six ways in which understanding evolves across the seven levels (see chapter 6) shows that sensemaking can be a process full of setbacks and problems. Moreover, the hierarchy allows for understanding to drop to a lower level. This is in contrast to the levels of situation awareness and the learning loop complex in information processing/analysis, where one can only improve to a higher level or stop on a current level. It is also not easy to drop to a lower level in Bloom's taxonomy, except perhaps by forgetting or not practicing an ability.

8.6 Wider context of sensemaking and sensemaking in the wider context

The findings will now be discussed in the wider context of sensemaking research and incident management.

8.6.1 *Wider context of sensemaking research*

One of the difficulties in sensemaking research is the interrelationship between sensemaking and related concepts, e.g. situation awareness, decision making, communication and problem solving. Sensemaking has been described as

- the process to create situation awareness (Hutton et al., 2008; Helsloot, 2007),
- preparation for decision making (Weick, 1995),
- part of the decision making process (Klein et al., 2007a; Helsloot, 2007; Weick, 1993),
- understanding if there is a problem and what it is (Weick, 1995; Klein et al., 2006a; Klein et al., 2007),
- based on and progressed by communication (Dervin, 1992; Landgren and Nulden, 2007; Landgren, 2005; Dervin, 1980).

The above mentioned activities are all crucial during incident response. The literature suggests that sensemaking is part of e.g. decision making and situation awareness. This means that a study that focuses on sensemaking will automatically comprise elements of some of the above mentioned activities. Drawing a sharp boundary around each one to exclude the others seems not possible.

"*The nature of complex cognition is that it occurs in packages of functions and processes rather than in single, sequential entities or causal chains of such things as long-term memory. The cognitive elements emerge in a fluid and flexible manner and shift readily in response to the dynamic nature of the environment*" (Crandall et al., 2006:145).

The same authors showed the variety of cognitive functions and processes of a battleground commander who faced an unexpected situation. Mental simulation, mental

models and option generation were defined as processes that served the function of sensemaking. Contrary, in the present study sensemaking was the process that served understanding as function. For the reason of intertwined cognitive processes the processes shown in the present study might also be "contaminated" with elements of e.g. decision making. Using a focus on cognitive processes it will not be possible to further distinguish sensemaking from other concepts, e.g. situation awareness or problem solving. The reason for this is that specific cognitive processes are not uniquely attributable to one or the other concept. For instance, mental projection is a process found in studies on situation awareness (Endsley, 1995a), recognition-primed decision making (Klein, 1998) and sensemaking (Klein et al., 2007a).
When the focus is on the function of sensemaking, then it is possible to make finer distinctions. However, this brings its own problems because every research domain might define sensemaking in their own context, resulting in a wide variety of definitions. As demonstrated in the literature review (chapter 3), definitions can be distinguished by function: information representation, fusion and exploitation, preparing a course of action and decision making or building situation awareness.
The focus of the current study was on the function of understanding an event. While acknowledging an overlap with other functions, the findings of the present research allow to characterise sensemaking in more detail for the function of situational understanding. Thus, moving on from the previously adopted definition of sensemaking as "*the deliberate effort to understand events*" (Klein et al., 2007a:114) the following definition is suggested:

"Sensemaking is a cognitive process that consists of at least one stage, along which situational understanding evolves and takes the form of multiple levels that distinguish "what is going on", "what can be done" and "performance of doing something", where each stage has a specific purpose and can be triggered by one or a variety of underlying mechanisms."

The following Table 8-7 relates the elements of the proposed definition to the results of the research:

Elements of the proposed definition on sensemaking as situational understanding	**Link of definition elements to more detailed study findings**
Sensemaking is a cognitive process that consists of at least one stage,	combining the elements of sensemaking context, activities (cue creation, retrieval and use), cues (direct/indirect) and (interim) understanding – see chapter 5
along which situational understanding evolves	in one or a combination of at least six ways (improvement, stays on same level, improves on the same level, drops to a lower level etc.) – see chapter 6
and takes the form of multiple levels that distinguish “what is going on”, “what can be done” and “performance of doing something”,	possibly seven levels, where levels 0-3 = what is going on; level 4-5 = what can be done; level 6 = performance of doing something. – see chapter 6, 7
where each stage has a specific purpose	which is just develop understanding (simple process), address limited understanding (emergent process), take understanding further (multiple stage process), address one of multiple gaps (multiple gap process) – see process variations in chapter 5
and can be triggered by one or a variety of underlying mechanisms.	which are cognitive mechanisms, the need to understand, situational mechanisms – see chapter 6, 7

Table 8-7 - A proposed definition of sensemaking as situational understanding, linked to study findings

8.6.2 Wider context of incident management

Literature suggested that sensemaking is crucial in incidents. The tasks of the incident commander include sensemaking to understand and maintain the big picture and co-ordinate the response. The preferential right of sensemaking is with the commander (Landgren, 2005). While this view is correct in terms of ultimately deciding the response, it paints the picture of sensemaking being focused on one commander. The episodes investigated in this study highlight that sensemaking is also a vital activity for officers further down the command chain, for two reasons. First, there are situations that personally affect people and require sensemaking. Second, there are situations that require sensemaking and subsequent communication with the incident commander. This was evident in episodes where the incident commander asked others to find out what is going on and report back to him, e.g. safety situation on scene. While the current study focused on individual sensemaking, there might be a need to communicate the sense made to others, e.g. incident commander or group. This communication is important because the commander might not be located on scene and rely on verbal reports to understand what is going on (Arbuthnot, 2002). It might be worth to distinguish between situations that require individual sensemaking and events that require communication with others.

9/11 was an exceptional and large incident. Large incidents usually involve several layers of command: e.g. gold (strategic), silver (tactical) and bronze command (operational) (Elliott et al., 2002) as well as crew leaders and individual firefighters at the front line. The current study focused on sensemaking at the front line, rather than at tactical and strategic level. Sensemaking requirements, specific activities and cues as well as levels of understanding might differ from what was studied here. Consequently, future studies might investigate possible differences. This is required in order to overcome communication gaps. Communications might be structured in a way that is based on who needs to understand what. Thus, the insights from this study might have implications on communication practice.

The literature review showed that research in the fire fighting domain aims to develop new technology to support sensemaking. The purpose is to reduce cognitive workload and free capacity for thinking (Jiang et al., 2004). While this is an important aspect, the current study did not investigate how people interact with and use technology. The situations covered do not seem to be favourable for technology applications because of rapid situation development. Rather, the current research highlights the importance of sensemaking for the individual despite the potential use of technology. During incident command exercises (see chapter 2), the researcher had a personal communication with Fire Service persons who work in an incident command vehicle. In recent years a variety of new electronic displays and technology was introduced that is supposed to make command support easier. However, the new technology resulted in duplication of work effort rather than supporting command tasks. Reasons were slow running software, dependency on internet connections and time required for data entries. In this case technology turned out to be more of a hindrance than help. This emphasises the continued need for cognitive studies that are independent of technology but also studies for technology design that integrates effortlessly into work flow.

8.7 The researcher's reflection on sensemaking

The purpose of this section is to present the researcher's own ideas and reflection on the sensemaking process, especially the process start (see 8.7.1) and the variations (see 8.7.2). This is followed by reflection on the researcher's own sensemaking process and learning throughout this research (see 8.7.3).

8.7.1 Where does the sensemaking process start?

The examples given in chapter 5 demonstrated that each process variation has a basic process as basis. The basic sequence is just a minor variation of the basic process elements identified in literature and the theoretical framework used for analysis.
With the basic process the assumption is made that sensemaking context, e.g. novel cue or uncertainty, is a trigger for the process. However, it must be asked whether sensemaking does not actually take place in order to perceive a specific context. For example, what are the activities involved to perceive an event as uncertain? If a cue is perceived, then there must be some kind of cognitive process involved to evaluate if

meaning can be created for it or not. If not, then one would be in a situation that requires sensemaking. If yes, then sensemaking was already successful because meaning was created. Consequently, the view that sensemaking only occurs when we face unintelligible situations or the sensemaking contexts used in this study might be too narrow.

This has consequences for the way in which the findings of this study need to be interpreted.
The sensemaking episodes in this study do not all have the same starting point. Some start with the noticing of novel, salient cues. These are the episodes where the diagrams show the first process stage as data driven. Adopting the view of Weick et al. (2005) it is argued that these cues are initially meaningless. The process now follows the simple structure to create initial understanding. If the understanding is satisfactory, the process might stop (simple process) or move on to a higher level (multiple stage process). If the understanding is limited, then a loop is entered (emergent process) to address this limitation. In the emergent and multiple stage process the sensemaking context might change to uncertainty or ambiguity. In these cases sensemaking leads to the creation of the traditional sensemaking contexts that are cited in the emergency response domain.
The process diagrams also show episodes that do not begin with salient, novel cues. These are the episodes where the first process stage was marked as goal driven. Taking the above argument that sensemaking needs to take place to perceive an event as uncertain or ambiguous, it has to be recognised that the process was not described or mapped from the very start but from an interim stage.
This difference explains why some episodes in this study begin with noticing novel cues (data driven), whereas others begin with another sensemaking context (goal driven).

Taking the above arguments it is suggested that sensemaking processes start with noticing a cue which carries initially no meaning and are thus data driven. It is also suggested that researchers should recognise that where they study sensemaking that begins with contexts other than novel, salient cues they are not looking at the very beginning of the process.
How people decide what cues to pay attention to and which ones are singled out as critical ones or ignored is also an important question. However, this is covered elsewhere (Fiske and Taylor, 1991; see e.g. Starbuck and Milliken, 1988) and was not part of this study.

8.7.2 Basic process sequence and variations

The findings suggest that there is a basic process sequence that people follow and that the identified process variations are different combinations of it. So, why is it necessary to distinguish between process variations when one could simply use the basic sequence?

Comparison during data analysis and diagram development showed that there are two types of episodes. One is where a single variation (not the meta-models) was found, e.g. the simple or multiple stage process occurs on its own. Another is where multiple variations occur in a sequence. The episodes where one coherent, uninterrupted sensemaking process could be identified were analysed first. This led to stabilisation of identified variations before episodes with longer sensemaking processes that seemed to be interrupted or incoherent in some way were analysed. These interruptions or incoherences in episodes had several reasons. First, it could be that a time lag occurred between two sensemaking processes that both belong to the same challenge. Second, a thematic change was apparent, i.e. one process seemed to be finished but the individual continued thinking about another aspect of the situation. Also, thinking about another sensemaking challenge constitutes a thematic change. Third, rapid situation development constantly provides new cues that are paid attention to, meaning that each time a new process is started to make sense of them. Fourth, the result of an insight might be action but after some time sensemaking continues because there is a need to understand how the situation is developing. These reasons resulted in combining several process variations in one episode because it seemed evident that a new sensemaking process was started rather than the previous one continued.

This emphasises the finding that the sensemaking process is fragmented, split into specific stages and interim insights occur at each stage.
It is tied to a specific event which might require several processes to understand its different aspects. In order to demonstrate that the process is fragmented it is more useful to show the individual process variations rather than one continuous diagram. One sensemaking episode is broken down into smaller sensemaking episodes. This could mean that sensemaking is a more fragmented process than previously described. Weick (1995) suggested that sensemaking is ongoing. While the researcher agrees in principle with this, it should also be added that sensemaking can be discontinuous. The reason for this is that within one episode sensemaking might be interrupted and later continued, action taken before a process is continued, it might take place at different locations and at different times.

There is another reason why process variations were used; namely, to emphasise differences in the process which could not be shown using the simple process only. Table 5-6 in section 5.3.1 provided a summary of process variations and differences between them. Differences exist because gaining understanding might be

- straightforward,
- limited and this needs to be corrected,
- a matter of building on already gained insights,
- require a multitude of cues versus only one or two,
- involve addressing multiple gaps,
- successful but trigger a new gap.

To make differences stand out it was necessary to illustrate them as process variations. However, it would have been possible to reach the same findings using the simple process only. This might have been a more consistent approach because problems with assigning a specific variation were encountered in several episodes (26, 32, 40, 47, 54). These episodes could be mapped in different ways. The problem of not being able to consistently apply each variation could be overcome by just using the simple process. This means that using a number of predefined process variations is a less flexible approach. Moreover, one can never be sure that there are not in fact more process variations than were identified in the data.

8.7.3 Reflection on the researcher's sensemaking and learning

The purpose of this section is to revisit the origin of interest for this study (section 1.1) and reflect on the researcher's own sensemaking and learning throughout the study.

The interest of sensemaking in the context of an emergency situation originated from the researcher's own experience of having to react to an armed robbery. This study has only partially helped to explain my own sensemaking process. The emergent and multiple stage processes seem adequate descriptions for some of my thinking episodes. Also, level 2, 3, 4 and 5 reflect some of the understanding I gained. Sensemaking theory also helped me to understand why I came up with a number of specific thoughts. Once confronted with a novel situation and not really knowing what to do, one falls back into trained patterns of behaviour and thinking. This was also previously described as part of recognition-primed decision making (Klein, 1998) as well as sensemaking (Weick, 1995).

Being a student of sensemaking has helped to some extent with the research process, analysing results and determining what findings mean. It raised awareness towards taking a step back and placing findings in the context of what is already known. It taught me not to be frightened of sitting in front of a large amount of apparently meaningless data. The concept of "any small reference point will do" to start making sense has proven to be useful, i.e. the construction of larger sense from smaller structures. However, a negative side effect has been to question everything another person says or writes. The attempt to make sense is hindered by constantly searching for possible ambiguities, uncertainties and meanings in conversations and texts. This culminates in not being able to come up with definite and precise statements. Knowing more about sensemaking does not necessarily result in a better ability to make sense.

8.8 Reflection on methodology, strengths and limitations

The purpose of this section is to present the researcher's reflection on the adopted methodology as well as strengths (see section 8.8.1) and limitations of the study (see section 8.8.2).

It needs to be kept in mind that the adoption of a specific theoretical framework for analysis limits the results that can be found. The framework constitutes a set of blinkers for the researcher, meaning that what one looks for and finds in the data is to some extent pre-determined. Grounded theory is supposed to somewhat overcome this problem by being led by patterns found in the data. However, neither Glaser's (1992) nor Strauss and Corbin's (1990), nor Charmaz's (2003) constructivist version overcome this problem. The reason why they fail to overcome it, lays in the way in which sensemaking works. Without a reference point to start making sense of data there is nothing to make sense of. Thus, the theoretical framework for analysis is a reference point for the researcher to analyse and make sense of data. Without framework there is nothing to look for in the data. Without structure, reference point or frame to compare data to, meaning cannot be created (Klein et al., 2007a; 1995; Sieck et al., 2007; Weick, 1993). Sensemaking requires structure. Thus, the researcher's findings are a reflection of the choices made during the research design phase, including the theoretical

framework. If there is reasonable confidence in the correctness of the theoretical framework, then there should be reasonable confidence in the correctness of the findings.
In this study the aim was to study the sensemaking process. The study of processes raises the question of which elements are chosen for investigation. The researcher's choice was based on the literature review. Comparison of research on sensemaking processes revealed that, independent of the application area, the commonality was that crucial process elements are: sensemaking context as trigger, activities to create and use cues, cues as input, and understanding as output (Klein et al., 2007a; Weick, 1995; Dervin, 1984; Dervin, 1992; Sieck et al., 2007; Weick et al., 2005; Russell et al., 1993; Ntuen, 2006a; Pirolli and Card, 2005; Qu and Furnas, 2005). Because of the wide basis in empirical and theoretical research the researcher had reasonable confidence in the correctness of choice of process elements and therefore theoretical framework for data analysis. This choice then limited the results in terms of what could be found, not only in terms of the sensemaking process structure but also in terms of underlying mechanisms. It raises the question of how complete the results are and if there are process elements or underlying mechanisms missing.

In line with the constructivist realist paradigm and constructivist Grounded Theory approach the findings of this study have to be regarded as incomplete slices of a reality.
It is incomplete because only some elements of sensemaking were considered and not every element is observable in the real domain at all times. It is a slice because people can never be fully aware of cognitive processes and completely explain their experience. Moreover, it cannot be claimed that the account of sensemaking processes and underlying structures is ever complete. It is "a" reality because people might create different meanings for the same event and thus construct different versions of reality. This reflects the nature of sensemaking.

8.8.1 Strengths

The purpose of this section is to point out strengths of the research. This includes aspects on variety, focus on real-world context, level of detail in the study and flexibility of the research approach.

Considering variety

The research process includes narrowing down the study scope to a researchable project. However, focusing on a specific phenomenon does not mean that variety should be lost. Keeping variety in form of multiple actor perspectives, situations and scenarios is important for showing differences and exceptions. It contributes to robustness and comprehensiveness of the research.
Variety was kept by including a diverse set of emergency exercises as well as interviews to inform the study. This was important to let the data show the way ahead for the research. Variety in sensemaking was shown, as the findings included successful, interrupted and unsuccessful processes as well as brief and long episodes. A variety of challenges (14 different ones) is included in the 9/11 study, instead of focusing on a single one. Typical operational tasks as well as life threatening situations were part of the research. Keeping this variety was important because it reflects the reality of a real-world incident.

Focus on a real-world context

The earlier parts of the study included emergency exercises, while the researcher-led interviews focused on a diverse set of real events and the main study on a single event in its real-world context. Thus, sensemaking was not studied in an experimental setting but in the context of a real incident in a real-life setting. This means that the problems associated with studying a phenomenon in an artificial setting were overcome.

Level of detail in sensemaking processes

The study showed a higher level of detail in the sensemaking process than other studies that focus on high-level activities. Although it is a time consuming and tedious approach, the high level of detail was required to investigate what happens inside process stages. This was required to take into account that the sensemaking process takes twists and turns, jumps between contexts and topics, is interrupted and discontinuous. It was also required because existing models did not originate from the emergency domain. Rather than assuming that their high level activities are applicable in the current study context, the researcher decided to start fresh, which requires going into detail. Once a detailed lens was applied, one can then zoom out to a high-level view and focus on more abstract stages.

A research approach that allows flexibility

A flexible approach was required because the topic originated from a personal interest of the researcher. Not knowing exactly where the topic development would lead to, the first research question was kept relatively open. Thus, a grounded approach was required to let the data lead the way and allow the topic and insights to evolve. This is reflected in the progression of study setting, data collection method, data characteristics and level of detail in findings, i.e.

- from personal experience to undemanding table-top exercises, demanding real-time and full-live exercises, to real incidents
- from observation to questionnaire and interviews
- use of primary and secondary data; from short answers in questionnaires, to semi-structured interviews to free flowing narrative with a high level of detail
- from inventory like, fragmented data on single aspects of sensemaking to detailed accounts on the whole process.

8.8.2 Limitations

The limitations addressed in this section cover sensemaking process elements, data quality, researcher bias and triangulation issues.

Sensemaking process elements

There are, of course, more elements in a process that can be studied, e.g. resources, constraints, enablers, the availability and effect of time, relationship to the environment, influence of stress on cognitive performance. Taking all these elements into account different process structures might have been found. However, to narrow down the study scope and keep the research manageable it was decided to focus on the core elements. Moreover, the data source might not have been good enough to provide comprehensive description of these additional elements.

Also frames and their relation to currently perceived cues, according to Weick (1995) the substance of sensemaking, have not been considered here.
By connecting a current cue to a frame of reference (e.g. a historic experience or story) it becomes meaningful. Considering frames in this research would have meant to enquire all the references individuals made. However, a systematic study of this might not be possible as relating cues to frames of reference could be an unconscious process that happens in a split second and that people are not aware of.
The episodes used in this study featured situations that lasted a couple of seconds to a couple of minutes and in some cases tasks were ongoing. It might be argued that time should have been chosen as variable for comparison of episodes. However, Weick's (1995, 2010) work indicates that having the right cues, the right framework and making the right connection between them determines if one can make sense (see section 3.2.1). Thus, having an infinite amount of time available to make sense of a situation would not help if one has not the right framework or cannot make required connections. Equally, a split second might be enough time to understand (see Landgren, 2005 in section 3.1.5) if the right cues, framework and connection come together. Whether understanding can be achieved and to what level seemed to be more important for the sensemaking process than the time component. Time was therefore not considered as a variable in this study.

Data quality
Taking the above arguments it cannot be claimed that this research has resulted in a complete picture of the sensemaking process. However, the question of data quality needs to be considered with regard to whether people can accurately report on their sensemaking process. Nisbett and Wilson (1977) found that people may not be able to reliably report on their mental processes that cause specific behaviour, as these might be unconscious. However, they also emphasise that accurate introspection is not impossible (Hurlburt and Heavey, 2001). At least it is possible for people to report on their experiences, assessments and what they actually did in situations (Endsley et al., 1998; Hurlburt and Heavey, 2001; Kellogg, 1982). Individuals' reports will comprise e.g. thoughts, actions, analogies, feelings, examples and conflicts. This is what was required for the present research rather than accurate descriptions of the exact mental process. It is similar to the narrative approach used by Barton and Sutcliffe (2009) to obtain detailed accounts of personal experiences and behavioural information.

Researcher bias
The researcher needs to be careful not to introduce bias into the research process, during data collection and analysis. As secondary data was used, there was no danger of influencing interviewees through the researcher's questions. It is acknowledged that subjectivity in processes of data coding, category development, analysis and interpretation cannot be completely avoided. The history, background and knowledge of the researcher will influence these processes. Also the choice of literature for discussion plays a role in determining the meaning of results. The researcher took care in the analysis process, using several iterations of checking the coding structure on consistency and accuracy. Researchers might use third party coding checks and inter-rater agreements as precaution against bias. However, these are also subjective and potentially biased. Moreover, this research did not attempt to create a comprehensive, universal theory, which depends on each single coding category. In the present research, the abstract process structures and variations did not directly depend on the detailed

coding categories, which only provide the meat to the bones. The levels of understanding constitute new coding categories that focus on a different aspect of the process, rather than building on previous categories. As such, there were no overarching themes identified, which is in line with the constructivist grounded theory. Also, the interviewees describe their experience of events. This means that the data comprises subjective emotions, feelings, hunches, perceptions, uncertainties and does not focus on objective facts of sensemaking. The constructivist grounded theory aims to account for meaning construction rather than objective truth. It therefore accepts that researcher's follow up their own ideas and new analytic insights, which constitutes the acceptance of at least a limited degree of bias. For these reasons coding checks by others were not used.

Triangulation

Triangulation is an important way of overcoming limitations of using a single source of data and/or method. It was originally planned to have at least two different sources of data, i.e. the 9/11 interviews as well as interviews conducted with officers of the UK Fire Services. As described in section 2.2.7 the latter were conducted but did not deliver the desired results. Thus, for reason of data quality they had to be excluded, leaving the researcher with secondary data only. An attempt was made to find at least an alternative set of secondary data, similar to the 9/11 records. Records on public enquiries regarding fire incidents as well as transcripts of cockpit conversations during aviation incidents were identified as possible sources. However, on closer inspection the same data quality issues were found as before. For this reason it was decided to carry out the research based on the 9/11 interviews only.

8.9 Research quality

The researcher must pay special attention to the quality of a study. This is especially the case in qualitative research where there is no one right way of collecting and analysing data (Creswell, 1994). Consequently, a variety of measures are available to ensure research quality. Reliability, validity and generalisability are the traditional criteria but the wording has been changed to better reflect the nature of qualitative research in a wide variety of research paradigms (Creswell, 1994). The list of practical quality measures by Miles and Hubermann (1994) reflects this. This list is followed to demonstrate the quality of the current study and shows in which section of the thesis they have been considered.

Objectivity/Confirmability

This was ensured by taking the following steps:

- Detailed description of data collection (see 4.5, 4.6), sample choice and procedure to identify sensemaking episodes (see 4.6), diagram development and showing the transition from raw data to process diagrams (see 4.7.2, 5.3.2.1, 5.3.3.1, 5.3.4.1, 5.3.5.1, 5.3.6.1, 5.3.7.1) and levels of understanding (see 4.7.2, Appendix D1-D7),
- Use of condensed data displays to support conclusions (see 5.3.1, 6.1, 6.3, 8.1),
- Detailed description of research methods and analysis procedures (see 4.3, 4.4, 4.7),

- Description of underlying assumptions and theoretical framework guiding analysis (see 4.7.1),
- Raw data in form of interviews is available for other researchers in the public domain (see *The September 11 Records* in references section), Appendix B1 shows a sensemaking episode guide. It shows which pages from which interview became which sensemaking episode number in this study.

Reliability/Dependability/Auditability

This was ensured by taking the following steps:

- Formulation of clear research questions, including description of how they came about (see 1.1-1.3, 4.4.1),
- Specification of research strategy and basic paradigms (see 4.2, 4.4.2) and description of how they are suited with methods used (see 4.4.2),
- Description how the findings relate to theory and research approach (see 8.2-8.5, 8.8),
- Following clear interview selection procedure (see 4.5, 4.6) and description why the data is suitable for this research (see 4.3, 4.5, 8.8).

Internal validity/Credibility/Authenticity

This was ensured by taking the following steps:

- Use of context rich descriptions using examples from the raw data (see 5.3.2.1, 5.3.3.1, 5.3.4.1, 5.3.5.1, 5.3.6.1, 5.3.7.1, Appendix D1-D7),
- Considering rival explanations for underlying mechanisms (6.3),
- Findings on categories and types of sensemaking activities and cues replicated in aircraft evacuation exercise (see 8.10.2),
- Areas of uncertainty by showing exceptions (see 5.3.2.2, 5.3.3.2, 5.3.4.2, 5.3.6.2, 5.3.7.2, 8.7.1, 8.7.2),
- Consulting experts to confirm that findings adequately reflect the reality of incident commanders' thinking and are consistent with their own experience (see 7.2.1, 7.2.2),
- Explanation for why triangulation was not used (see 4.5, 8.8.2),
- Coherent explanation for not checking conclusions with original interviewees (see 8.8.2).

External validity/Transferability/Fittingness

This was ensured by taking the following steps:

- Description of sample and setting characteristics to allow comparison (see 1.7, 4.5, 4.6),
- Discussion of limitations to generalisation of findings (see 8.8.2, 9.3),
- Expert review to confirm that findings are transferable to the wider domain of incident response and command as well as potential practical applicability in command training (see 7.2.5, 7.2.6),
- Connecting findings to existing theory, showing differences, similarities and advances (see summary tables and text in 8.2, 8.3, 8.4, 8.5).

8.10 Utilisation of findings

The following two sections describe how the findings might be used in sensemaking research (section 8.10.1) as well as training for emergency responders (section 8.10.2).

8.10.1 Research practice

This section describes how the findings might be used for modelling sensemaking processes, studying sensemaking and tracing understanding.

The variety of existing approaches in studying sensemaking processes means that there is no formalised modelling structure. The basic process might be useful for researchers who want to model sensemaking processes in detail. As such the simple process might provide a template that allows the construction of sensemaking processes, showing process stages as well as a nested overall structure.

Based on the insights of this study a list of elements that might be considered to study and analyse sensemaking processes is proposed. This might be used as a guideline for questionnaire and interview design as well as framework for analysis of sensemaking processes:

- Name of the sensemaking challenge: What was sensemaking about?
- Sensemaking context: What causes process to start and why?
- Activities in the process: Cue creation, retrieval, use
- Cue type: Direct, indirect, non-definitive, unsatisfactory, action?
- Sensemaking context changes: What context changes? When do they occur and why?
- Loops in the process: What loop types occurred with what outcome?
- Sequence of activities and cues used, strategies used
- When was sensemaking successful and when did it fail? Why?
- When and how does the process continue or stop?
- What made you enter this process stage?
- What was to be understood? Are there process phases dedicated to gaining a specific type of understanding?
- What was the consequence of gaining understanding, e.g. specific action possible?
- When an action was performed, how did it inform sensemaking?

The development of the hierarchy of understanding makes it possible to trace its development throughout an episode. This is illustrated in the following Figure 8-1 and Figure 8-2. This might be useful in sensemaking experiments, where participants are confronted with a puzzling situation. However, it might not be possible to use the here proposed levels of understanding because they might be different in non-emergency contexts.

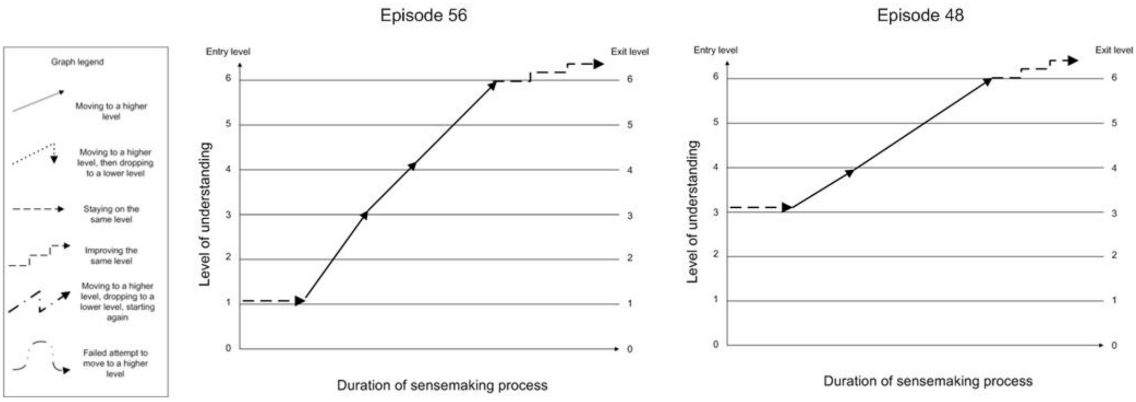


Figure 8-1 - Comparison of two individuals' evolving understanding in the same situation: Escape from a dust filled garage under zero visibility

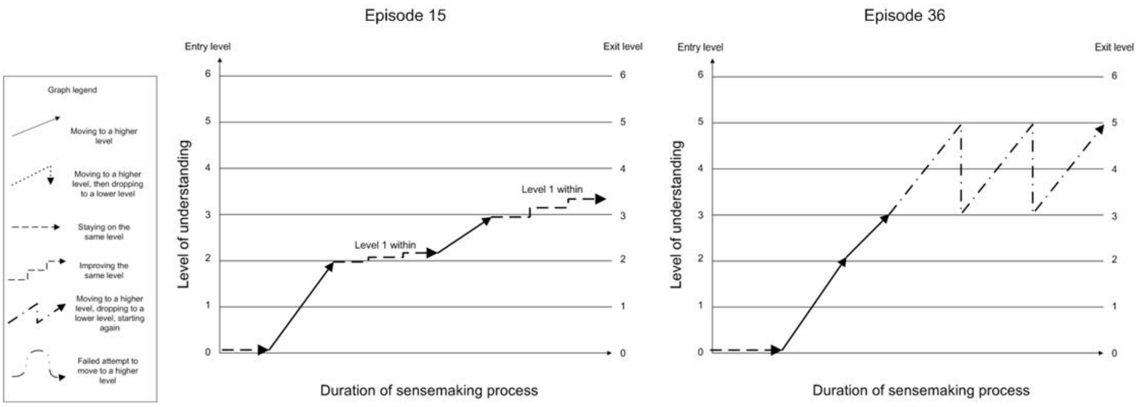


Figure 8-2 - Comparison of two individuals' evolving understanding in the same situation: Fleeing from a collapsing tower without seeing what happens

Similarities and differences in individuals' evolving understanding can be highlighted when comparing multiple episodes on the same instance. The above visualisation could be used to compare differences in expert/novice sensemaking. Further questions could be asked about critical activities and cues that allow one person to progress quicker than others.

8.10.2 Training practice

Table 5-1 in chapter 5 distinguished sensemaking activities and cues, i.e. activities to create and use cues as well as direct and indirect cues. These categories distinguish process components based on their origin (direct/indirect cues) and purpose of an activity (cue creation/retrieval/use). It might provide predefined categories that could be used by other researchers who analyse sensemaking processes. The categories were tested if they be found in another context using data obtained from participants in simulated aircraft evacuation trials (see chapter 2). All categories for activities to create and use cues as well as direct cues were found, e.g. audible cues and sources of information (cabin crew), experience (previous trials), local knowledge (aircraft cabin layout), procedural knowledge (of evacuation). For indirect cues we found all but two categories in the data (building state, smoke/flames), e.g. options (multiple exit options), safety and hazard (areas to avoid, passenger behaviour). This suggests that the activity categories and many cue categories might be applicable across different application domains. However, the form that cues take within a category seems to be domain specific, i.e. fire fighters use different cues than soldiers or managers.

There is a practical implication of this finding for incident management training. Adapting Table 5-1 to specific environments could serve as useful guideline for decision game development. Tactical decision games, which are used as low-fidelity exercises for emergency management in many domains (Crichton and Flin, 2001; Crichton et al., 2000) usually focus on decision making and developing a course of action under time pressure. Understanding a problem or situation precedes decision making. Objectives for a tactical decision game could include the identification of critical cues that help to gain understanding as well as their source and how they can be created.

Weick (2002:11) reported on a communication protocol used in wild land fire fighting during briefings. The protocol follows the structure of:
"*Here's what I think we face; here's what I think we should do; here's why; and here's what we should keep an eye on. Now talk to me!"* This structure allows briefing participants to keep their understanding of a situation current. The levels of understanding from this research might be useful in developing a similar communication protocol: Here is what I think is happening (level 1), this is what is confirmed to be happening (level 2), these are the (potential/immediate/future) consequences (level 3), here is what we could/can do because… (level 4-5), we have done this so far with that effect (level 6). This protocol would allow to make uncertainties explicit (level 1 and 3) as well as include monitoring progress on actions.

As shown in section 3.1.7, previous studies have described sensemaking challenges for fire incident commanders. The analysis has shown that specific challenges tend to occur either at specific stages or around specific events of an incident (see 5.1.2 and Appendix C2). This means that sensemaking challenges can be divided into three groups:

- incident development independent (should happen in any incident), e.g. understanding the incident, understanding command post location;
- incident development dependent (can but does not have to happen in an incident), e.g. what's happening, unknown risk;
- extreme cases (rare challenges), e.g. disbelief.

This does not mean that challenges belonging to the first group occur more often than the ones in the second group. Rather it means that the first group is relevant mainly for the incident commander and support command, whereas challenges of the second group might be faced by any responder across ranks.
The consequence of this insight is that not only incident command training could be structured around these challenges. Special training measures might be developed in the future around challenges that one can be sure to face, ones that are most likely to be faced and exceptional cases.

The expert review also confirmed the potential value of the findings for incident command training (see chapter 7).

9 Conclusion

This chapter aims to convey

- How the research questions were addressed (see section 9.1),
- What the research contributed to knowledge and how identified gaps were addressed (see section 9.2),
- What areas of future research are suggested (see section 9.3).

9.1 Addressing the research questions

Research question one (RQ1) was the starting point of the study:

“What process do individuals follow to make sense of events during an emergency?”

RQ1 was addressed in several stages, which included topic development. Data was collected in a series of emergency exercises and interviews:

- Emergency exercises, including organisational crisis management, aviation crises, aircraft evacuation and fire incidents (duration approximately 9 months)
    - Exercise 1: 12 questionnaires,
    - Exercise 2: Observation,
    - Exercise 3: 9 questionnaires,
    - Exercise 4: 23 questionnaires,
    - Exercise 5 : Observation, 40min of video material,
    - Exercise 6: 76 questionnaires,
- Interviews with officers of the UK Fire Service (duration approximately 3 months)
    - 6 interviews, 50 pages of transcribed interviews,
- 9/11 study – interviews with NYFD members on their experience of the response on 9/11 – secondary data (duration approximately 14 months),
    - 21 interviews (115 pages of transcribed material) used to extract 59 sensemaking episodes (37 pages of transcribed material).

This was accompanied by a literature review on sensemaking, the sensemaking process and sensemaking in the context of incidents. Insights from each exercise and interview informed the research and determined the next steps. The grounded theory approach was chosen to keep flexibility in topic development and let the data lead the way to the final topic area, suitable research setting and most appropriate data and data collection method. This progression is evidenced in

- The move from personal experience to undemanding table-top exercises, demanding real-time and full-live exercises, to real incidents,
- The move from observation to questionnaire and interviews,
- The use of primary and secondary data; from short answers in questionnaires, to semi-structured interviews to free flowing narrative with a high level of detail,

- The move from inventory like, fragmented data on single aspects of sensemaking, e.g. challenges or cues, to detailed accounts on the whole process.

The exercises and the researcher-led interviews (see chapter 2) constitute an exploratory phase, resulting in methodological, data and research setting requirements for the main study. The main results to answer RQ1 originate from the 9/11 interviews (see chapter 4 for justification of suitability), i.e. the six process variations and that the process progresses in distinct stages. This constitutes a pattern in the data. The discovery of this pattern triggered the question to find out what underlying mechanisms could cause it. This resulted in research question two (RQ2):

"Why do stages occur in the sensemaking process?"

Just as the grounded approach describes, the data and analysis were leading the way for further investigation; this time not by collection of more data but by re-analysing the same data from another perspective. The results for RQ1 and a subsequent extended literature review (chapter 3 part 2) resulted in initial cues as to what might be underlying mechanisms. Four potential mechanisms were tested in the data (referred to as cognitive factors in chapter 7). However, they did not consistently explain the process stages. Consequently, the data was analysed again to search for alternatives. This resulted in the described hierarchy of understanding with seven levels, needs to understand and situational factors.

The findings were discussed in relation to existing literature (chapter 7), where it was shown how they advance current knowledge. Finally, the results were reviewed and commented on by experts from the UK Fire Services.

9.2 Contribution to knowledge

The literature review on sensemaking in the fire fighting domain showed that there is a lack of studies on the sensemaking process, its structure and understanding. The following four gaps were identified:

Gap 1: Limited understanding of how sensemaking context develops in the sensemaking process, i.e. if, how, why it changes and what the consequence is.

Gap 2: Limited understanding of what stages exist in the sensemaking process and how they are linked with evolving understanding.

Gap 3: Limited understanding of what sensemaking process structure people in the emergency response domain follow, what process variations exist and what their purpose is.

Gap 4: Limited understanding of what is understood at intermediate stages and the end of the sensemaking process, if different levels of understanding can be identified and how understanding evolves along the process.

The current study has contributed to knowledge on the process that people follow to make sense during the response to an emergency situation, i.e. build and improve situational understanding and underlying mechanisms that can trigger process stages. This was summarised in Figure 6-2 in chapter 6, section 6.3. The following Figure 9-1 shows the results in the work context of fire commanders.

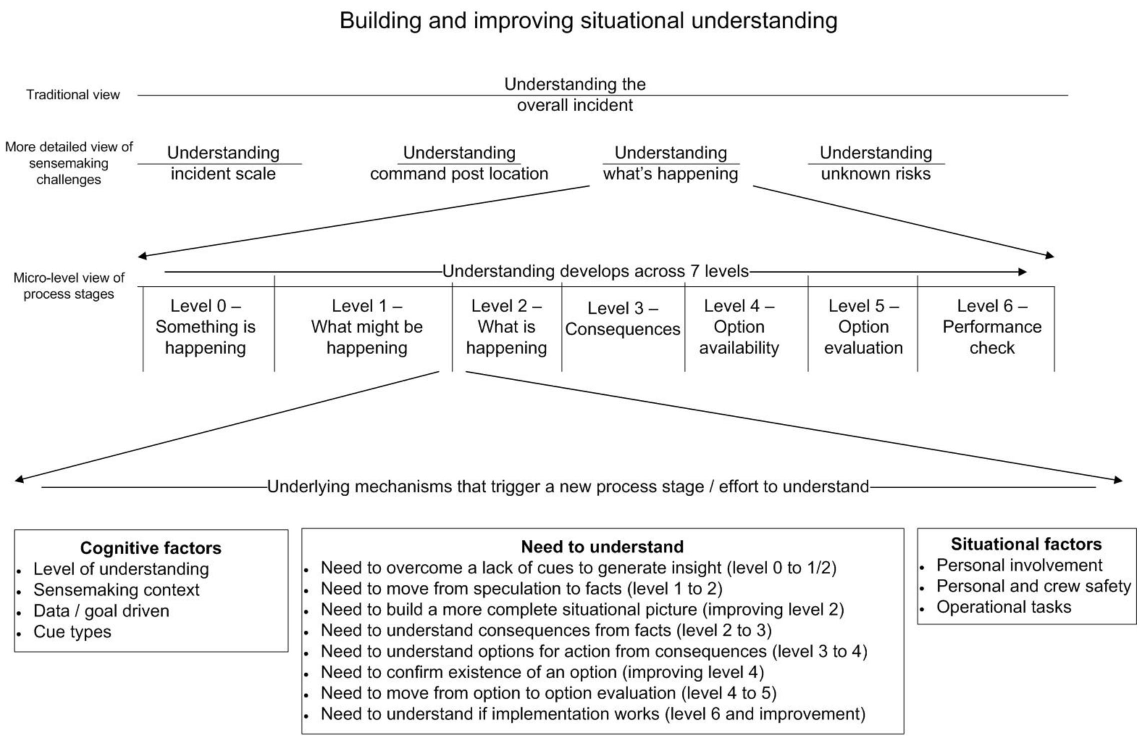


Figure 9-1 - Building and improving situational understanding in the context of incident response

The traditional view is that incident commanders need to understand the overall incident. The incident can be broken down into several sensemaking challenges. This study has applied a micro-level view to investigate the process to make sense of these individual challenges. Further investigation revealed three groups of underlying mechanisms that trigger stages in the process. These stages are tied to levels of understanding.

The contribution can be separated into three parts: process structure, understanding as process outcome and their inter-relationship. The new insights of this study were shown in the discussion chapter in Table 8-1 to 8-6. These insights will be related to the literature gaps in the following paragraphs.

The findings of chapter 5 contribute to a better understanding of sensemaking processes in terms of their structure, variations and purpose.

Table 8-2 in chapter 8, section 8.3 stated that:

> The sensemaking process consists of at least one stage that follows a basic structure. The basic structure (simple process) and identified variations (emergent process, multiple stage process, multiple input process, multiple gap and gap-triggers-gap process) offer a detailed view, demonstrating that the

purpose of a process stage can be to address limited understanding, taking it to a higher level, addressing multiple gaps or situation aspects. This offers a micro-level view of more high-level activities shown in existing sensemaking process models, e.g. elaborating frames. Process stages are tied to gaining understanding, expressed here in form of seven levels.

These findings serve to answer RQ1, address gap 3 (process structure, variations and purpose) and partly gap 2 (process stages and link to evolving understanding).

The findings also contributed to understanding that sensemaking is not necessarily a continuous process but a fragmented one. The advantage of using process variations instead of a single process model is that: individual process fragments can be shown; combinations of several process variations can be shown. This approach allows showing that within the same sensemaking episode people encounter problems or take understanding to a higher level. The greater level of detail is useful because it shows that the sensemaking process for a specific situation can be split into several smaller fragments, where sensemaking can be e.g. successful, unsuccessful, about overcoming difficulties to understand something or building on previous insights.

The findings of chapter 6 make a contribution by providing new knowledge on underlying mechanisms that can trigger sensemaking process stages, on what understanding is gained as a consequence of sensemaking and how it evolves throughout the overall process. The findings serve to answer RQ2 and provide complimentary answers to RQ1.

Table 8-6 in chapter 8, section 8.5 showed that:

In the context of this study it was found that the stages of the sensemaking process result in situational understanding that takes the form of a seven level hierarchy, which is structured from the general to the specific:

Level 0 - Understanding that something is happening
Level 1 - Understanding what might be happening
Level 2 - Understanding what is happening
Level 3 - Understanding consequences
Level 4 - Option generation
Level 5 - Option evaluation
Level 6 - Performance evaluation

The seven levels can be summarised as follows:

- Understanding what is going on (level 0-3)
- Understanding what can be done (level 4-5)
- Understanding performance of doing something (level 6).

This extends the current view of sensemaking in form of understanding “what is going on” and “what can be done” by including “understanding performance of doing something”. Understanding develops across the seven levels in six different ways, showing how it evolves along the process.

These findings address gap 4 (levels of understanding, evolving understanding, link between process stages and understanding) and gap 2 (process stages and link to evolving understanding).

Table 8-3 in chapter 8, section 8.4.1 presented the following:

> This research identified four cognitive factors as underlying mechanisms of process stages: change in sensemaking context, change between data- and goal-driven sensemaking, two descriptive cue types (non-definitive and unsatisfactory cue) as well as insufficient level of understanding. However, they are not consistent explanatory factors because they tend to occur in different combinations and they are not found in every process variation.

These findings address gap 1 (sensemaking context development within the process).

Table 8-4 in chapter 8, section 8.4.2 stated that:

> Understanding is gained at each process stage. Seven levels of understanding were found that can be expressed as eight needs to understand:
> - Need to overcome a lack of cues to generate insight (level 0 to 1/2)
> - Need to move from speculation to facts (level 1 to 2)
> - Need to build a more complete situational picture (improving level 2)
> - Need to understand consequences from facts (level 2 to 3)
> - Need to understand options for action from consequences (level 3 to 4)
> - Need to confirm existence of an option (improving level 4)
> - Need to move from option to option evaluation (level 4 to 5)
> - Need to understand if action implementation works (level 6 and improving level 6)
>
> This provides a more detailed view of what specifically fire crews and incident commanders try to understand than current literature offers.

These findings address gap 4 (levels of understanding, evolving understanding, link between process stages and understanding) and gap 2 (process stages and link to evolving understanding).

Table 8-5 in chapter 8, section 8.4.3 stated that:

> The nature of operational tasks, personal and crew safety as well as personal involvement in a situation are triggers of the sensemaking process in general as well as its stages.

This means that searching for underlying mechanisms in the cognitive domain is not enough. Mechanisms of a cognitive process can also be found in situation aspects and work context.

The combination of results in chapter 5 and 6 contributes to better understanding of the link between the sensemaking process, sensemaking context and understanding.

The traditional start point (sensemaking context) and traditional end point (understanding) are shown to matter during the process in form of changing sensemaking context and interim understanding gained at process stages. Table 8-1 in section 8.2 states:

> By taking a holistic view of the sensemaking process and adopting a formalised process structure (basic structure: trigger, activities, input, output) new insights could be gained on the role of sensemaking context and understanding, traditionally shown only as trigger and output of the overall process. Sensemaking context can change during the process and is a trigger of process stages. Understanding is gained at each process stage and evolves throughout the process.

These findings address gap 1 (sensemaking context development within the process), gap 2 (process stages and link to evolving understanding), and gap 4 (levels of understanding, evolving understanding, link between process stages and understanding).

9.3 Future research

This study has generated new insights into the sensemaking process, its structure, underlying mechanisms and understanding as (interim) output. However, it cannot be claimed that the list of process variations, underlying mechanisms or levels of understanding is complete or definite. Consequently, future research is required to investigate if there are other process variations, other underlying mechanisms that trigger process stages and other levels of understanding.

Moreover, the focus of the study was on the fire fighting domain and emergency response context. Future research is required to test if the sensemaking process structures, underlying mechanisms and levels of understanding can be found in non-emergency settings and emergency settings other than fire fighting. This would help to understand potential differences between sensemaking in emergency and non-emergency settings.

It cannot be claimed that the specific process variations and the seven level hierarchy of understanding are applicable 1-to-1 in other study settings. However, the researcher believes that the insight of sensemaking progressing in stages and the general concept of levels of understanding can be transferred to other research domains. Thus, testing is required to identify what form the stages and what form understanding takes in other work contexts, e.g. intelligence analysis, information processing.

This study focused on individuals involved in operational tasks of fire fighting (bronze level). Section 8.10 outlined possible utilisation of findings in training of emergency responders, i.e. communication practice and training around sensemaking challenges. Due to time constraints it was not possible to try applying the findings in training practice. This might be done in future studies.

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Appendices

Appendix A1- Questionnaire Exercise 1

Dear Sir / Madam,
Thank you very much for participating in this online survey.
It only takes around 10 minutes to complete the survey, and all views expressed will remain strictly confidential.
There are two types of questions in the survey. If you are asked to describe or explain something, please click on the text box provided to type in your response. To answer a multiple choice question, please click on the appropriate button where a green dot will highlight your choice.
To start the survey, please click on the button “Next question” at the bottom of the page.
Thank you very much for your time and help to make this project a success. Your contribution is highly appreciated. If you have any questions about the project please do not hesitate to contact me.
Kind regards,
Johannes R. Bayer
(contact details)

1. Please state your gender
2. Have you participated in a crisis management exercise before?
3. In what way was the experience from previous exercises helpful for dealing with the tasks of "Exercise Phoenix"?
4. Have you ever been involved in managing a real incident?
5. In what way was the experience from managing a real incident helpful for dealing with the tasks of "Exercise Phoenix"?
6. "The following questions refer to the experience of managing a severe incident and what might be difficult about it.

This part of the survey is based on your experience of dealing with the questions you had to answer during each phase of “Exercise Phoenix” and the decisions you had to make (e.g. who should make the decision to evacuate; if the media approach you what will you say about the situation, your staff and business; what resources do you have to implement your decisions?).
The answers you give can be based on either your own experience or what you observed or discussed with other group members.

7. Were there any situations during the incident in which you were not sure what to do?
8. Please describe the situation(s) where you were not sure what to do.
9. Please describe what helped you to make sense of what to do.
10. If there was nothing that helped you please click on the button "Next question" (at the bottom of the page).
11. Were there any situations during the incident that you found confusing?
12. Please describe the situation(s) that you found confusing.
13. Please describe what helped you to deal with the confusing situation(s).
14. If there was nothing that helped you please click on the button "Next question" (at the bottom of the page).

15. Were there any other situations during the incident that were difficult to understand but have not yet been mentioned?
16. Please describe the situation(s) that were difficult to understand.
17. Please describe what helped you to make sense of the above described situation(s).
18. If there was nothing that helped you please click on the button "Next question" (at the bottom of the page).
19.
20. "Imagine your best friend asks you the following question: "Suppose you are faced with a severe problem during an incident and you don't know what to do. What would help you to understand what you have to do?"
21. What advice would you give?

Thank your very much for participating in this survey. Please click on the ""Finish"" button to save and submit your answers.

Appendix A2 – Questionnaire Exercise 3

Sensemaking log for the crisis management exercise

Based on your experience of managing the crisis, please explain below **what you or your team had to make sense of.** (E.g. situations that were chaotic, confusing, unexpected or situations where you were not sure what to do, that were difficult to understand or …)	Please explain **what helped you or your team to make sense** of the situations you mentioned on the left, i.e. find explanations, understand what was going on and how to find a solution. (E.g. clues, rules of thumb, specific experience, skills, guidelines…)

Appendix A3 –Questionnaire Exercise 4

Questionnaire used after Fire Service incident command simulations

Exercise name:	
Your role in the exercise:	
Years of experience in the Fire & Rescue Service:	Gender:

Question 1:
Please describe the most challenging situation you faced in the exercise.

Question 2:
Please describe why this was challenging.

Question 3:
What were the key questions you asked yourself in this situation?

Question 4:

How did you answer these questions (were there any specific steps you followed)?

Question 5:

Please describe what specifically helped you to understand or deal with the situation / problem.

Question 6:
What support or advice could be given to others who face the same challenge or problem? (Please describe also what would have helped you, i.e. something that was not available but would have helped)

Thank you very much for your kind support.

Appendix A4 –Questionnaire Exercise 6

Dear Sir / Madam,

Thank you very much for participating in this online survey.

It only takes around 10 minutes to complete the survey online, and all views expressed will remain strictly confidential.

There are two types of questions in the survey. If you are asked to describe or explain something, please click on the text box provided to type in your response. To answer a multiple choice question, please click on the appropriate button where a green dot will highlight your choice.

To start the survey, please click on the button “Next question” at the bottom of the page.

Thank you very much for your time and help to make this project a success. Your contribution is highly appreciated. If you have any questions about the project please do not hesitate to contact me.

Kind regards,

Johannes R. Bayer
(contact details)

All following questions are about your personal experience of the four runs of the aircraft evacuation trial.
In case you were SEATED at the beginning of an evacuation run, the time from when you heard the command to evacuate until you had left the aircraft is of interest.
For the runs where you were NOT SEATED, the time from the moment you entered the cabin until you had left the aircraft is of interest.

1. Please state your gender

- ○ Male
- ○ Female

2. Have you participated in aircraft evacuation trials before?

- ○ No
- ○ Yes

3. Please describe what you think was the most difficult during the evacuation runs.

4. Please explain why it was difficult.

5. Please explain what helped you to make sense of the situation mentioned above, i.e. understand what was going on and how to find a solution?

If there was nothing that helped you making sense please go to QUESTION 14 (at the bottom of the page).

Please indicate HOW MUCH the things that helped you to make sense ARE RELATED to the categories below using a scale from 1 to 5, where 1 is "Not at all related" and 5 is "Very much related".

	1 - Not at all related	2 - Slightly related	3 - Neither slightly nor much	4 - Much related	5 - Very much related
6. Help from the flight crew	○	○	○	○	○
7. Using experience from similar situations	○	○	○	○	○
8. Following instinct	○	○	○	○	○
9. Just following the behaviour of other passengers	○	○	○	○	○
10. Trial and error	○	○	○	○	○
11. Making a conscious, rational decision	○	○	○	○	○
12. Behaving based on your own plan	○	○	○	○	○
13. Trying to find clues on what to do without help from other people, e.g. looking for exit signs	○	○	○	○	○

14. What else did you find difficult?

15. Was there any situation that you found confusing?

○ No

○ Yes

16. Please describe what you found confusing.

17. Please describe what helped you to deal with the confusing situation(s).

If there was nothing that helped you to deal with the situation please click on the button "Next question" (at the bottom of the page).

Please indicate HOW MUCH the things that helped you to deal with the confusing situation(s) ARE RELATED to the categories below using a scale from 1 to 5, where 1 is "Not at all related" and 5 is "Very much related".

	1 - Not at all related	2 - Slightly related	3 - Neither slightly nor much	4 - Much related	5 - Very much related
18. Help from the flight crew	○	○	○	○	○
19. Using experience from similar situations	○	○	○	○	○
20. Following instinct	○	○	○	○	○
21. Just following the behaviour of other passengers	○	○	○	○	○
22. Trial and error	○	○	○	○	○
23. Making a conscious, rational decision	○	○	○	○	○
24. Behaving based on your own plan	○	○	○	○	○
25. Trying to find clues on what to do without help from other people, e.g. looking for exit signs	○	○	○	○	○

26. Was there any situation in which you were not sure what to do?

○ No

○ Yes

27. Please describe the situation(s) where you were not sure what to do.

28. Please describe what helped you to decide what to do.

If there was nothing that helped you to decide what to do please click on the button "Next question" (at the bottom of the page).

Please indicate HOW MUCH the things that helped you to decide what to do ARE RELATED to the categories below using a scale from 1 to 5, where 1 is "Not at all related" and 5 is "Very much related".

	1 - Not at all related	2 - Slightly related	3 - Neither slightly nor much	4 - Much related	5 - Very much related
29. Help from the flight crew	○	○	○	○	○
30. Using experience from similar situations	○	○	○	○	○
31. Following instinct	○	○	○	○	○
32. Just following the behaviour of other passengers	○	○	○	○	○
33. Trial and error	○	○	○	○	○
34. Making a conscious, rational decision	○	○	○	○	○
35. Behaving based on your own plan	○	○	○	○	○
36. Trying to find clues on what to do without help from other people, e.g. looking for exit signs	○	○	○	○	○

37. Was there anything that became easier the more evacuation runs you participated in?

○ No

○ Yes

38. Please describe what became easier.

39. What advice would you give your best friend on how to behave during an aircraft evacuation?

Thank your very much for participating in this survey. Please click on the "Finish" button to save and submit your answers.

Dear Sir / Madam,

Thank you very much for your time and effort to complete and submit the

questionnaire.
Your participation in this study is very much appreciated.

If you have any concerns or questions about any aspect of this study, please do not hesitate to contact Johannes Bayer, the researcher in charge.

In case you would like to receive a summary of results from this study, please contact Johannes.

Contact details

Appendix A5 – Coding structure Exercise 6

- **Activities to determine exit route**
  - Activities used to figure out clues
    - Assessment and comparison
    - Listening
    - Observation
    - Planning exit route beforehand
    - Process of elimination
    - Reposition to get better view
    - Taking time to observe and assess
    - Using local knowledge
  - Criteria for exit route change
    - Aisle congestion level
    - Clue failure (crew instructions)
    - Clue failure (crowd)
    - Exit congestion
    - Opportunity cost of changing
    - Queue speed at exit
    - Speed of people flow
  - Degree of flexibility in exit routes
    - fractured exit route, i.e. several decisions
    - highly flexible, i.e. late choice or frequent change
    - one non-changeable exit route
  - Timing of activity
    - After getting out of the seat
    - before evacuation
    - during evacuation
  - Timing of exit route decision
    - At the seat
    - further away from exits
    - Near exits
  - Use of single or multiple criteria
    - multiple
    - single
- **Audible clues**
  - Audible clue attributes
    - Blurred by noise or other voices
    - instructions given actively and early
    - Loud shouting
    - Many shouts at the same time from different crew members
    - Not clear enough
    - Not loud enough
    - Repetition of instructions
    - right expectation
  - Audible clue failure
    - contradictory instructions
    - instructions not understandable
    - Too many shouts at same time = no help
    - Understanding meaning
  - Audible clue origin
    - Cabin crew shouting
  - Back-up clues
    - Common sense - assumptions
    - Follow the crowd
    - Observe what other passengers do
    - Own clue (exit comparison)

- Clue combinations
  - crew instructions and following others
  - instructions and exit comparison, distance, availability
  - Instructions and knowledge of alternative exit locations
  - instructions and own clue (identify alternative exit)
  - instructions and seeing behaviour of others
  - seeing and hearing crew
- Effect of audible clue
  - Confusion
  - Helps to focus and bring attention in hectic
  - Other clue required
  - Reassurance
  - Solved unsure what to do (exit change)
  - Stress induction
- Filtering noise required
- Type of audible clue
  - Direction to alternative exits
  - Directions to crew member's exit
  - Exit locator (can't see exits but follow the shouting)
  - Instruction to wait
  - Just hearing crew without understanding instructions
- What the clue helped with
  - Arriving at closed exit
  - Exit route decision
  - Finding alternative exit (congestion)
  - Focus and attention
  - Identify open exit
  - Locating exits when they are not visible
  - More orderly exiting to increase speed
  - Nothing - source of problem
  - Switching exit or not dilemma
  - Waiting at closed exit

Building and using local knowledge

- Activities to build knowledge
  - Comparing map with actual layout
  - Locating exits while being seated
  - Looking at cabin map
  - Memorising
  - Moving in the cabin
  - Observing to gain knowledge
- Clue combinations
  - Exit location and crew instructions
- Consequence - knowledge use and application
  - Attention to exit location
  - Collective group behaviour improved
  - Confidence increased
  - Confusion reduction
  - Flexibility
  - How to - process knowledge
    - Generating options
    - Getting to alternative exit
    - Locating exits
    - Navigating - moving easier
    - Planning exit strategy or route
    - Selecting exit route
    - Visualise exit route
  - Informed re-assessment of situation
  - Knowing clue location

Orientation improved
Knowledge attributes 0
experiential
external, tangible
Rough knowledge (not detailed)
Knowledge of what 0
Aisles
Behaviour of others
Cabin layout
Exit locations
Exit preferences
Exit routes, short cuts
How evacuation works
Location of all exits
Nearest exit
Timing
When is knowledge gained
As consequence of the evacuation
Before evacuation
During evacuation
Clues and activities used to prepare evacuation
Activities gone wrong
Map vs reality
Activities to prepare
Anticipating problems
Comparing cabin map with actual site
Devising escape plan
Studying cabin map
Visualising, mental planning, mental rehearsal
Clue type used
Cabin map
Escape plan
Knowledge of clue location
Mental plans, scenarios
Timing of preparation
Before evacuation
C**lues that fail to work**
Alternatives used
Assumptions
Escape plan modification, i.e. route adaptation
Exit congestion level to find alternative exit
Follow crowd
Instinct + rationality
Observe behaviour of others
People flow speed
Process of elimination
Clue type
Availability of exit
Crew instruction
Escape plan
Follow crowd
Consequence
Confusion
Corrective action
Surprise
Unsure what to do
Use of alternative clue
Failure attribute

- Correctable
- external clue
- fixed clue, e.g. sign
- flexible clue, e.g. people instructions
- Own clue
- Uncorrectable
- Unforseen incident

Reason for failure
- Change in conditions
  - Availability change
  - Number of people suddenly increased
  - People flow
- Language ability
- Many voices in the air
- Noise
- Own clue is flawed
- People perception

Expectation and knowledge of people behaviour

Behaviour attributes
- Acting together as a group
- Behaviour - opportunistic - attitude
- Collaborative passenger behaviour during the evacuation
- Common behaviour
- Competitive passenger behaviour during the evacuation
- Crowd might get it wrong
- Disorderly passenger behaviour during the evacuation
- Flow of people
- Group affected by individual behaviour
- Group overrides own intention
- People - number of, surge of
- Physical contact with other passengers
- Random
- Safety

Expectations were formed

Knowledge grew as consequence of trials

Following other passengers

Alternative clues
- Cabin crew instructions
- Instinct
- Mindful decision making
- Own situation assessment

Clue reliability
- 2nd clue should be used
- Alternative clue should be used
- High
- Low = don't follow or avoid if you can
- Medium, other clues might be necessary

Complimentary clues
- Cabin crew instructions
- Exit signs
- Fast moving speed
- Instinct
- Mindful decision making
- Own escape plan
- Own observation to locate best exit
- Own situation assessment

Location
- Further away from the exits

        Near the exits
    Reason to follow others
        Choosing between alternative exits
        Disorientation
        Locating exits
        Not knowing where to go
        Other clue failed
        Understand that evacuation is happening
Formulation of aims that guide behaviour
    Aim characteristics
        Attitude towards how you should behave
        Pursuing aim with determination
    Aim consequences
        Collaborative behaviour, i.e. helping and safety of others
        Competitive and opportunistic behaviour
    Aim priorities
        Primary aims
        Secondary aims
    What aims
        Evacuate as quickly as possible
        Not getting crushed by others
        Save your own life
    What aims help with, purpose
        Competitive behaviour of others
        Coping with fear
Judgement criteria for exit choice
    Activities to support judgment
        Comparing exit conditions
        Experiencing exit condition
        Get better view
        Observation of condition at one particular exit
        Process of elimination
        Take some time
        Wait as long as possible with decision
    Consequences
        Change of exit route
        Choice of alternative exit
        Looking for alternative exit
        No option but to queue
        Speeding up exit
    Criteria chains
        Congestion level and moving speed at exit
        Crew shouting, congestion level
        Crew shouting, proximity, congestion
        Follow the crowd and congestion level
        Get better view, comparison of exit conditions
        Proximity, congestion level, ease of access
    Criteria priority
        Primary criteria
        Secondary criteria
    Exit characteristics
        Able to see exit condition
        Congestion level
        Exit availablity, i.e. closed
        Exit preference of other people
        Flow of people towards exit
        Moving speed at exit
        Proximity

- Proximity and congestion level

Observation - experience of passenger behaviour
- Consequence
  - Confirmation of own behaviour
  - Escape plan modification
  - Indicator that other source of information is needed
  - Indicator that you have no option but to got with the flow
  - Indicator what one should do, i.e. follow or not to follow
  - More determined behaviour
- Problem addressed
  - Competitive behaviour
  - Confusion
  - Exit route choice
  - Unsure what to do
  - Which exit to choose
- Type of behaviour that is a clue
  - Being swept away by the crowd
  - Everybody shows this behaviour
  - Failure of others
  - Help from others
  - No pattern of people flow observed
  - Others follow instructions to wait
  - Passengers pushing at exit from behind
  - Pattern of people flow observed
  - Seeing other passengers waiting
  - Speed of movement
  - Surge of people in a part of the cabin

Trial and error
- Cause for using trial and error
  - Confusing cabin layout
  - Confusion
  - Confusion from people flow
  - Information overload by 2 crew members
  - No solution to exit choice problem
  - No solution to exit path choice
  - Seeing others fail with obvious solution
  - Several exits with congestion
  - Unsure what to do
- Trial and error type
  - Trying out exit paths
  - Trying out more than one exit
  - Trying out planned path
  - Trying to locate exit by following others
  - Trying which exit works for quick evacuation

Use of escape plans
- Ability to plan
  - As consequence of evacuation
- Avoid planning
- Escape plan changes
  - Accept changes
  - Congested exits
  - Instinct when plan fails
  - Willingness to change
- Escape plan components, ingredients
  - Back-up plan
  - Cabin map
  - Exit locations
  - Familiarity with cabin layout

- Mental preparation activities
    - Anticipating problems
    - mental planning of various routes
    - Visualising escape route
- Plan helps with
    - Alternative to following others
    - Confidence of direction despite people flow
    - Confusion
    - Independence from crew instructions
    - maximum no of doors encountered
    - Quick evacuation
- Timing of preparation
    - Before evacuation
    - When seated

Using assumptions to guide behaviour

- Complimentary clues
    - Common sense
    - Following other passengers
    - Instinct
    - Overall evacuation goal
- Using assumptions to
    - Create mental scenario
    - Decide on exit
- What assumptions
    - Availability of alternative exits
    - Cabin crew instructions
- Why assumptions needed
    - Other clue failed

Using mental scenarios

- Scenario of what
    - Exit choice
    - Mental plan of one exit route
    - Mental plan of routes to several exits
    - Potential exit conditions
    - Scenario of what might go wrong
    - Visualising exit route
    - Weighing two options to choose

Visual clues

- Clue combinations
    - Map and experience of real site
- How visual clues are used during evacuation
    - Actively looking for exit signs
    - Exit route decision
    - Exit route planning
    - Following exit signs
    - Locating exit
    - Orientation
    - Reassurance for action
- Timing of clue use
    - Before evacuation
    - During the evacuation
- Visual clue type
    - Cabin crew
    - Cabin map
    - Exit signs
    - Safety briefing material, emergency procedures

Appendix A6 – Interview questions for UK F&R Service officers

I am interested to find out what helps you to deal with challenging situations. Specifically I am interested in non-routine situations that are very difficult to understand or make sense of.

Examples are situations

- where it is not immediately obvious what the problem is or what is going on
- that are chaotic
- where usual procedures or equipment do not work
- a novel situation that you had never been in before
- where something unexpected or surprising happened

I am especially interested in everything that helped you to understand these exceptional situations.

I am going to ask you to tell me about some events that stand out in your mind as the top challenges or toughest issues from your past experience. I am going to ask you what happened, why it was challenging, what questions and thoughts you had, and what helped you to understand the situation.

The aim of my research is to identify practical strategies to deal with these situations in order to develop training material for the Fire & Rescue Service.

Q1: Please tell me about your current job and your background? (how long in the F&R Service, rank, IC)

Think back over all the times you have responded to incidents. I'd like you to choose some events that stand out in your mind as the top challenges or toughest issues you had to understand / make sense of. I am looking for situations e.g. where it was not immediately obvious what the problem is or what was going on, that are chaotic, where usual procedures or equipment do not work, a novel situation that you had never been in before, where something unexpected or surprising happened. These can be some small episodes from different incidents.

Q2: Could you just briefly describe the situations that come to your mind

Q3: Why was this difficult / tough? [describes the gap]

Record description of the situation and sensemaking occasion. Ask further for the sensemaking occasion:

Q4: What were you trying to understand at this point and why? [gap detection, goal]

Q5: What questions did you have at this point?

Q6: What stopped you from better understanding the situation? (why did you have this question) [gap type, gap condition]

Q7: Did you have any thoughts or ideas or conclusions at that time? What were these thoughts or ideas or conclusions? [cue – type; origin]

> Q7.1 Did these thoughts or ideas or conclusions help you in any way? How did they help you? [cue – type / usefulness]

Q8: What did you do / use to understand the situation and why? [bridging the gap with actions and cues / cue creation strategy]

Q9: What was especially helpful to understand the situation and why? [cue type, what answers did you get from using this cue]

> Q9.1: [If nothing, then ask] Was there something that stopped you from understanding the situation? What? How? [gap characteristic]
>
> Q9.2: Was there anything that COULD HAVE helped you? What? How? [cue – alternatives]

Q10: Was whatever you used enough to understand the situation? Why? [cue – gap closure]

Q11: How important was understanding the situation and why? [gap importance]

Q12: What could be done to help others dealing with this situation?

Appendix B1 – Sensemaking episode guide

Sensemaking episode	Interview reference (Name and interview number)	Page numbers
1	Becker_Brian_9110019	3 - 5
2	Becker_Brian_9110019	6 - 8
3	Becker_Brian_9110019	8
4	Becker_Brian_9110019	10
5	Becker_Brian_9110019	11-13
6	Becker_Brian_9110019	15-17
7	Becker_Brian_9110019	17
8	Callan_Joseph_9110195	3
9	Callan_Joseph_9110195	4
10	Cassano_Salvatore_9110011	3-4
11	Cassano_Salvatore_9110011	4-6
12	Cassano_Salvatore_9110011	10-11
13	Coyle_John_9110406	2-3
14	Coyle_John_9110406	5-6
15	Coyle_John_9110406	8-10
16	Cruthers_Frank_9110179	5-6
17	Dixon, Brian 9110166	2-3
18	Dixon, Brian 9110166	3-4
19	Dixon, Brian 9110166	15-16
20	Fitzpatrick_Thomas_9110001	13-15
21	Garcia_Marshal_Louis_9110002	2-4
22	Garcia_Marshal_Louis_9110002	4-5
23	Garcia_Marshal_Louis_9110002	6-9
24	Garcia_Marshal_Louis_9110002	9-10
25	Garcia_Marshal_Louis_9110002	11-12
26	Garcia_Marshal_Louis_9110002	5-7
27	Gregory, Stephen 9110008	5-6
28	Gregory, Stephen 9110008	7
29	Hayden, Peter 9110139	2-3
30	Hayden, Peter 9110139	5-9
31	Henry, Edward 9110379	9-10
32	King, Stephen 9110208	7-10
33	King, Stephen 9110208	17-20
34	King, Stephen 9110208	23-24
35	McCahey, Rich 9110191	3

Table B1 – Reference guide for sensemaking episodes in the 9/11 study (part 1 of 2)

Sensemaking episode	Interview reference (Name and interview number)	Page numbers
36	McCahey, Rich 9110191	11-13
37	McCahey, Rich 9110191	13-16
38	Meyers, Harold 9110382	2-3
39	Nigro_Daniel_9110154	4
40	Nigro_Daniel_9110154	5-6
41	Nigro_Daniel_9110154	8
42	Nigro_Daniel_9110154	8-10
43	Nigro_Daniel_9110154	13-14
44	O'Flaherty, Brian 9110431	12-15
45	Pfeifer, Joseph 9110138	5-6
46	Pfeifer, Joseph 9110138	12-13
47	Picciotto_Richard_9110211	5-7
48	Sudnik, John 9110198	4-6
49	Turi, Albert 9110142	3-4
50	Turi, Albert 9110142	19-20
51	Turi, Albert 9110142	9
52	Turi, Albert 9110142	7-10
53	Turi, Albert 9110142	10-12
54	Turi, Albert 9110142	8-14
55	Turi, Albert 9110142	14
56	Turi, Albert 9110142	15-16
57	Turi, Albert 9110142	19
58	Turi, Albert 9110142	8-9
59	Vallebuona, Tom 9110418	5-6

Table B1 – Reference guide for sensemaking episodes in the 9/11 study (part2 of 2)

Appendix B2 - Coding structure of the 9-11 study

Sensemaking context

- Sensemaking context - Ambiguity
- Sensemaking context - Complexity
- Sensemaking context - confusion
- Sensemaking context - Context change
- Sensemaking context - expected event missing, surprise
- Sensemaking context - Information load
  - Sensemaking context - Information load - High
  - Sensemaking context - Information load - Low
- Sensemaking context - Information quality low
- Sensemaking context - Plausibility
- Sensemaking context - Salient, novel cues are noticed
- Sensemaking context - Turbulence
- Sensemaking context - Uncertainty
  - Sensemaking context - Uncertainty - Effect uncertainty
  - Sensemaking context - Uncertainty - Performace uncertainty
  - Sensemaking context - Uncertainty - Response uncertainty
  - Sensemaking context - Uncertainty - State uncertainty
- Sensemaking context - unexpected event

Activity type

- Cue creation
- Cue use and creation activity
- Deliberate cue creation
- Non-deliberate cue creation

Cue type

- Action cue
- Alternative cue
- Back-up cue
- Complimentary cue
- Confirmatory cue
- Context changing cue
- Cue chain
- Cue composite
- Direct cue
- Indirect cue
- Information source cue
- Mental vehicle
- Multiple cue
- Non-definitive cue
- Single cue
- Unsatisfactory cue
- Up-dated cue

Sensemaking models

- Driver - data driven sensemaking
- Driver - goal driven sensemaking
- Level 0 sensemaking - act first, don't ask why
- Level 1 sensemaking - what might happen
- Level 1 to level 2 switch
- Level 2 sensemaking - what is happening
- Level 3 sensemaking - consequences
- Level 4 sensemaking - option generation
- Level 5 sensemaking - option evaluation
- Level 6 sensemaking - performance check
- Sensemaking models - emergent

Sensemaking models - Gap triggers gap
Sensemaking models - gap within gap
Sensemaking models - multiple gap
Sensemaking models - Multiple input generation
Sensemaking models - multiple stage
Sensemaking models - Multiple stage - variation 1
Sensemaking models - Multiple stage - variation 2
Sensemaking models - Multiple stage - variation 3
Sensemaking models - Multiple stage - variation 4
Sensemaking models - Multiple stage - variation 5
Sensemaking models - Multiple stage - variation 6
Sensemaking models - Multiple stage - variation 7
Sensemaking models - Multiple stage - variation 8
Sensemaking models - reverse sensemaking
Sensemaking models - simple
SMI quality

SMI strategy

SMI strategy - a trusted source needs no confirmation
SMI strategy - act first make sense later
SMI strategy - Build increased sense as you go along
SMI strategy - changed situation dynamics require sensemaking
SMI strategy - confirm sense by what others do
SMI strategy - Find and use source of local knowledge
SMI strategy - ignoring information
SMI strategy - Mental what-if scenario
SMI strategy - probing information quality
SMI strategy - Seek confirmatory information
SMI strategy - stop sensemaking process
SMI strategy - Test for changed situation dynamics
SMI strategy - Tracing steps backwards
SMI strategy - Trial and error
SMI strategy - unsatisfactory outcomes require data collection
SMI strategy - Using SMIs sequentially
SMI strategy - visualisation of incident

SMI type - activity

SMI type - activity - assessing
SMI type - activity - assessing - checking assumption
SMI type - activity - assessing - comparison activity
SMI type - activity - assessing - onsite assessment
SMI type - activity - assessing - re-assessment
SMI type - activity - assessing - risk assessment
SMI type - activity - assessing - Waiting for development
SMI type - activity - create confirmatory SMI
SMI type - activity - Deliberating
SMI type - activity - Deliberating - considering alternatives
SMI type - activity - Deliberating - Explanation attempt
SMI type - activity - Deliberating - hypothesising about incident
SMI type - activity - Deliberating - Inference
SMI type - activity - Deliberating - initial explanation check, comparison, plausibility check
SMI type - activity - Deliberating - thinking ahead
SMI type - activity - information collection
SMI type - activity - information collection - Reconnaisance unit
SMI type - information collection activity - As you go along
SMI type - information collection activity - purposeful, specific
SMI type - information collection activity - Random
SMI type - activity - Mental projection
SMI type - activity - Mental projection - anticipation of problems
SMI type - activity - Mental projection - Tracing steps

SMI type - activity - Mental projection - visualisation, projection
SMI type - activity - sensegiving
SMI type - activity - sensegiving - Passing on information
SMI type - activity - sensegiving - directing orders
SMI type - activity - sensegiving - helping others to make sense
SMI type - activity - sensegiving - Prepare others for sensemaking
SMI type - activity - Trying out alternative option
SMI type - activity - trying out one option
SMI type - activity - Using senses
SMI type - activity - Using senses - feeling
SMI type - activity - Using senses - Listening
SMI type - activity - Using senses - observation from distance
SMI type - activity - Using senses - observation from safe place
SMI type - activity - Using senses - observation of crowd
SMI type - activity - Using senses - seeing for yourself
SMI type - following others
SMI type - not following others
SMI type - object
SMI type - object - absence of problem
SMI type - object - Audible cues
SMI type - object - Audible cues - Falling objects
SMI type - object - Audible cues - Location, direction
SMI type - object - Audible cues - Plane sound
SMI type - object - Audible cues - Roaring, exploding sound
SMI type - object - Audible cues - Voices
SMI type - object - Command and control
SMI type - object - Command and control - Assignments
SMI type - object - Command and control - command structure
SMI type - object - Command and control - current command post location
SMI type - object - Command and control - primary efforts
SMI type - object - Command and control - primary efforts - Evacuation
SMI type - object - Command and control - primary efforts - Fire fighting
SMI type - object - Command and control - primary efforts - Preserve life
SMI type - object - Command and control - primary efforts - Search and rescue
SMI type - object - Experience - analogy
SMI type - object - Experience - pilot
SMI type - object - Experience build-up
SMI type - object - experience from past incidents
SMI type - object - Explanations and assumptions
SMI type - object - Explanations and assumptions - Alternative explanation
SMI type - object - Explanations and assumptions - assumptions
SMI type - object - Explanations and assumptions - Contradiction
SMI type - object - Explanations and assumptions - estimation
SMI type - object - Explanations and assumptions - expectations
SMI type - object - Explanations and assumptions - initial explanation
SMI type - object - Explanations and assumptions - More plausible explanation
SMI type - object - Explanations and assumptions - Scenario
SMI type - object - Explanations and assumptions - up-dated explanation, assumption...
SMI type - object - Fire and building dynamics
SMI type - object - Fire and building dynamics - building state
SMI type - object - Fire and building dynamics - building state - Building structure
SMI type - object - Fire and building dynamics - building state - collapse
SMI type - object - Fire and building dynamics - building state - Collapse trajectory
SMI type - object - Fire and building dynamics - building state - Damage extent
SMI type - object - Fire and building dynamics - building state - Damage location
SMI type - object - Fire and building dynamics - building state - Damage type
SMI type - object - Fire and building dynamics - building state - Floor conditions
SMI type - object - Fire and building dynamics - building state - structural stability

SMI type - object - Fire and building dynamics - smoke and flames
SMI type - object - Fire and building dynamics - smoke and flames - Fire burning characteristics
SMI type - object - Fire and building dynamics - smoke and flames - Heat
SMI type - object - Fire and building dynamics - smoke and flames - Location
SMI type - object - Fire and building dynamics - smoke and flames - Scale
SMI type - object - Fire and building dynamics - smoke and flames - Smoke characteristics
SMI type - object - Fire and building dynamics - speed
SMI type - object - knowledge 0
SMI type - object - knowledge - Fire behaviour
SMI type - object - knowledge - Health risk
SMI type - object - knowledge - knowledge objects
SMI type - object - knowledge - knowledge objects - Clipboard
SMI type - object - knowledge - knowledge objects - Command board
SMI type - object - knowledge - knowledge objects - means of communication
SMI type - object - knowledge - most current knowledge
SMI type - object - knowledge - procedural knowledge
SMI type - object - knowledge - procedural knowledge - communication structure
SMI type - object - knowledge - procedural knowledge - Dealing with specific incident
SMI type - object - knowledge - procedural knowledge - Incident location specific
SMI type - object - knowledge - structural stability
SMI type - object - local knowledge
SMI type - object - local knowledge - Building layout
SMI type - object - local knowledge - current position of resources
SMI type - object - local knowledge - Landmark, object location
SMI type - object - local knowledge - last known location
SMI type - object - local knowledge - location specific arrangement
SMI type - object - local knowledge - Street size and parking
SMI type - object - options 0
SMI type - object - options - available options
SMI type - object - options - Obvious option eliminated
SMI type - object - options - Several options
SMI type - object - options - unsatisfactory option
SMI type - object - procedures 0
SMI type - object - procedures - location specific
SMI type - object - Resources 0
SMI type - object - Resources - Available equipment and resources
SMI type - object - Resources - Available equipment and resources - Access
SMI type - object - Resources - Available equipment and resources - Usability
SMI type - object - Resources - capabilities
SMI type - object - Resources - Mobilised resources
SMI type - object - Resources - people condition
SMI type - object - Resources - people condition - deteriorating
SMI type - object - Resources - people condition - Fatality
SMI type - object - Resources - people condition - Injured
SMI type - object - Resources - people condition - Missing
SMI type - object - Resources - requirement
SMI type - object - Safety and hazard 0
SMI type - object - Safety and hazard - debris
SMI type - object - Safety and hazard - debris - Debris on the ground
SMI type - object - Safety and hazard - debris - Debris quantity
SMI type - object - Safety and hazard - debris - falling debris
SMI type - object - Safety and hazard - from people
SMI type - object - Safety and hazard - hazard
SMI type - object - Safety and hazard - hazard - Hazard zone
SMI type - object - Safety and hazard - hazard - Safe zone
SMI type - object - Safety and hazard - Safety distance
SMI type - object - situation dynamics 0
SMI type - object - situation dynamics - inevitability of consequence

SMI type - object - situation dynamics - Situation dynamics decreased
SMI type - object - situation dynamics - Situation dynamics increased
SMI type - object - situation dynamics - uncontrollable circumstance

SMI type - object - sources of info 0

SMI type - object - sources of info - colleagues
SMI type - object - sources of info - facial expression
SMI type - object - sources of info - Initial info from control centre
SMI type - object - sources of info - Radio communication
SMI type - object - sources of info - TV
SMI type - object - sources of info - alphanumeric beeper
SMI type - object - sources of info - Civilians
SMI type - object - sources of info - Commander in charge
SMI type - object - sources of info - Field comms
SMI type - object - sources of info - Multiagency - Ambulance
SMI type - object - sources of info - Multiagency - Law enforcement
SMI type - object - sources of info - Multiagency - OEM
SMI type - object - sources of info - On-site personnell
SMI type - object - sources of info - Situation up-date, briefing
SMI type - object - sources of info - specialist advice

SMI type - object - Surrounding area 0

SMI type - object - Surrounding area - Distance
SMI type - object - Surrounding area - space available
SMI type - object - Surrounding area - terrain layout

SMI type - object - visual cues 2

SMI type - object - visual cues - People behaviour
SMI type - object - visual cues - visibility
SMI type - object - visual cues - visibility - Vantage point
SMI type - object - visual cues - visibility - Zero

Gap type

Gap type - Command structure
Gap type - Disbelief
Gap type - How communicate with crew
Gap type - Information
Gap type - Information quality
Gap type - Location of resources
Gap type - on-site approach, directions
Gap type - orientation
Gap type - problem solving, unknown options
Gap type - resource requirements
Gap type - Understanding command post location
Gap type - Understanding the incident
Gap type - unknown incident scale
Gap type - unknown location (of hazard, fire, victim...)
Gap type - unknown risk
Gap type - What's happening (general situation awareness)

Appendix C1- Sensemaking challenges, frequencies, description and patterns

Sensemaking challenges	Frequency (Total =74)	%	Cumulative %	Challenge description (in general, patterns and data examples)
What's happening	21	28.38	28.38	General: Figuring out what is going on, a situational development or the cause for an event Pattern: 15 of 21 occurrences (=71%) when tower 2 and 1 collapse and shortly after the collapse Examples: Hearing a strange noise (episode 5, 12, 19, 28, 29, 36, 44, 46, 47, 57, 59), seeing a new situation development (episode 7, 9, 25, 28, 37), seeing debris falling (episode 9, 20), hearing only parts of a situation report (episode 10), seeing a facial expression and behaviour of a colleague and not knowing its cause (episode 15), a colleague's question (episode 55)
Unknown risk	12	16.22	44.59	General: Figuring out the risk of a situation, risk on site from falling debris, building up a picture of safety risks (operational and buildings) Pattern: 7 of 12 (almost 60%) when tower 2 and 1 collapse Examples: risk of being near the towers while debris is falling (episode 1), risk of leaving the lobby to go outside while debris is falling (episode 6), determine safe zone and danger zone (episode 7, 31), risk from changing environmental conditions (episode 9, 25), risk from being in a dust/debris cloud (episode 28, 50), unsure what safety risks exist in the towers (episode 32) and outside (episode 40), risk from available course of action (episode 36, 44)
Understanding the incident	10	13.51	58.11	General: understanding that the incident has happened, building up a picture of what has happened at fire station and en-route to the scene Pattern: Mostly at initial stage of the incident after arrival on scene (7 out of 10 = 70%) Examples: arrival on scene, assessing situation (episode 8, 32, 38, 40), assembling picture of the incident through multiple radio reports (episode 10, 29) or observation en-route (episode 18, 29, 43, 41) or calling command center (episode 35)

Table C1 - Sensemaking challenges in the 9/11 study: categories, frequencies and description (part 1 of 3)

Appendix C1- Sensemaking challenges, frequencies, description and patterns

Sensemaking challenges	Frequency (Total =74)	%	Cumulative %	Challenge description (in general, patterns and data examples)
Understanding command post location	7	9.46	67.57	General: understanding if the current location is suitable for the command post or whether it has to be moved and where Pattern: Mostly at initial stage of the incident Examples: not sure about where to find the command post (episode 2, 23, 41), suitability of current command post location (episode 11, 23, 27, 39, 52), not sure if command post still exists after tower collapse (episode 41)
Disbelief	5	6.76	74.32	General: implausibility of this event happening needs to be understood Pattern: Mostly at initial stage of the incident (60%) Examples: when information about the incident is first received it sounds implausible (episode 13) or taken as a joke (episode 17, 21), although seeing an event with own eyes it is not believed that this is happening (episode 14), inability to find reasonable explanation how this could have happened (episode 33)
Orientation	4	5.41	79.73	General: Finding a way under zero visibility conditions in a dust cloud after tower collapse Pattern: Immediately after tower collapse (75%) Examples: Orientation in a building to find the shortest way across (episode 34), finding a way under zero visibility conditions in a dust cloud after tower collapse (episode 16, 48, 56)
Information quality	3	4.05	83.78	General: The reliability or correctness of information is doubted Pattern: No pattern identified Examples: not being sure if all the latest and necessary information was received (episode 3), rumours about a possible situation development (episode 45), unsure about correctness of a new situation report (episode 54)

Table C1 - Sensemaking challenges in the 9/11 study: categories, frequencies and description (part 2 of 3)

Sensemaking challenges	Frequency (Total =74)	%	Cumulative %	Challenge description (in general, patterns and data examples)
Unknown incident scale	3	4.05	87.84	General: Collecting multiple pieces of information from multiple sources to get an idea of the incident scale Pattern: No pattern identified Examples: Listening to radio transmissions to get an idea of the incident scale (episode 10), which units are responding and type of alarm transmitted (episode 22), reconnaissance of incident scene to assess damage (episode 40)
Location of resources	3	4.05	91.89	General: Tracking location of deployed resources Pattern: No pattern identified Examples: Understanding description of location via radio (episode 23), co-ordination of resource deployment and task progress (episode 30, 53)
Unknown location (of hazard, fire etc.)	2	2.70	94.59	General: Understanding at what location an event takes place Pattern: No pattern identified Examples: Trying to determine location of fires from civilians (episode 4), reconnaissance to find out safety situation on scene (episode 32)
Command structure	1	1.35	95.95	Pattern: No pattern identified Example: No idea about existence of command structure after tower collapse (episode 42)
Resource requirements	1	1.35	97.30	Pattern: No pattern identified Example: Situation assessment to figure out resource requirement (episode 40)
On-site approach, directions	1	1.35	98.65	Pattern: No pattern identified Example: comparing different routes to get to the scene (episode 26)
How communicate with crew	1	1.35	100	Pattern: No pattern identified Example: Usual means of communication do not work (episode 24)

Table C1 - Sensemaking challenges in the 9/11 study: categories, frequencies and description (part 3 of 3)

Appendix C2 –Sensemaking challenge pattern of occurrence during 9/11

Case ID	Location	Time (E = Estimated)	What's happening	Unknown risk	Understanding the incident	Understanding command post location	Disbelief	Orientation	Information quality	Unknown incident scale	Location of resources	Unknown location (of hazard, fire)	Command structure	Resource requirement	On-site approach, directions	How communicate with crew
29	Fire station office	08:46 First plane hits WTC1	1	0	1	0	0	0	0	0	0	0	0	0	0	0
21	Playing golf on day off	08:50 just after first plane has hit WTC1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
10	Fire station office	08:50 just after first radio transmission that plane has hit WTC1	1	0	1	0	0	0	0	1	0	0	0	0	0	0
13	Fire station office	08:50 just after first radio transmission that plane has hit WTC1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
17	Fire station office	08:50 just after first radio transmission that plane has hit WTC1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
35	Outside Manhattan on way to work	08:50	0	0	1	0	0	0	0	0	0	0	0	0	0	0
43	En-route to scene	08:50	0	0	1	0	0	0	0	0	0	0	0	0	0	0
30	WTC1 operations command post in the lobby	08:50 - 10:00	0	0	0	0	0	0	0	0	1	0	0	0	0	0
1	On scene arrival on appliance	08:55	0	1	0	0	0	0	0	0	0	0	0	0	0	0
18	En-route to scene	08:55	0	0	1	0	0	0	0	0	0	0	0	0	0	0
8	Outside WTC1	08:55 - 09:03 reconnaissance of tower until 2nd plane hits	0	0	1	0	0	0	0	0	0	0	0	0	0	0
49	En-route to scene	08:55	0	0	1	0	0	0	0	0	0	0	0	0	0	0
14	Arrival on scene, near WTC1	08:57	0	0	0	0	1	0	0	0	0	0	0	0	0	0
2	Entering WTC1	09:00	0	0	0	1	0	0	0	0	0	0	0	0	0	0
3	WTC1 lobby at initial incident command post	09:01	0	0	0	0	0	0	1	0	0	0	0	0	0	0
39	At initial exterior command post of WTC1 which he	09:01	0	0	0	1	0	0	0	0	0	0	0	0	0	0
11	WTC1 Command post on West Street	09:06 shortly after 2nd plane hit	0	0	0	1	0	0	0	0	0	0	0	0	0	0
32	In WTC1, lobby and multiple floors	09:10 - 09:30	0	1	1	0	0	0	0	0	0	1	0	0	0	0
22	In the car en-route to the scene	09:10 after 2 5th alarms	0	0	0	0	0	0	0	1	0	0	0	0	0	0
40	At incident command post on West Street	09:10 after 2nd plane has hit WTC2	0	1	1	0	0	0	0	1	0	0	0	1	0	0
51	WTC1 lobby at initial incident command post	09:15 just after recommendation to move main incident command post	1	0	0	0	0	0	0	0	0	0	0	0	0	0
58	WTC1 lobby at initial incident command post	09:15 just after recommendation to move main incident command post	1	0	0	0	0	0	0	0	0	0	0	0	0	0
52	WTC1 incident command post which is being moved	09:20 just after recommendation to move main incident command post	0	0	0	1	0	0	0	0	0	0	0	0	0	0
26	En-route to scene	09:20	0	0	0	0	0	0	0	0	0	0	0	0	1	0
33	WTC1 operations command post in the lobby	09:20	0	0	0	0	1	0	0	0	0	0	0	0	0	0
27	WTC1 command post on the street	09:30	0	0	0	1	0	0	0	0	0	0	0	0	0	0
45	Lobby WTC1, operations command post	09:30	0	0	0	0	0	0	1	0	0	0	0	0	0	0
53	At incident command post on West Street	09:30	0	0	0	0	0	0	0	0	1	0	0	0	0	0
4	Stairwell WTC1	09:30 when rumour of 3rd plane was around	0	0	0	0	0	0	0	0	0	1	0	0	0	0
23	Near WTC1 command post	09:40	0	0	0	1	0	0	0	0	1	0	0	0	0	0
24	Near WTC1 command post	09:41	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table C2 - Sensemaking challenges matched against 9/11 timeline (part 1 of 2)

Appendix C2 –Sensemaking challenge pattern of occurrence during 9/11

Case ID	Location	Time (E = Estimated)	What's happening	Unknown risk	Understanding the incident	Understanding command post location	Disbelief	Orientation	Information quality	Unknown incident scale	Location of resources	Unknown location (of hazard, fire)	Command structure	Resource requirement	On-site approach, directions	How communicate with crew
9	Lobby WTC1, operations command post	09:50,10mins before first collapse	[illegible]	1	0	0	0	0	0	0	0	0	0	0	0	0
54	At incident command post on West Street	09:58	0	0	0	0	0	0	1	0	0	0	0	0	0	0
5	Stairwell WTC1, about floor 30	09:59 WTC2 collapse	1	0	0	0	0	0	0	0	0	0	0	0	0	0
12	West Street	09:59 WTC2 collapse	1	0	0	0	0	0	0	0	0	0	0	0	0	0
15	In the streets near command post	09:59 WTC2 collapse	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0
20	At incident command post on West Street	09:59 WTC2 collapse	1	0	0	0	0	0	0	0	0	0	0	0	0	0
25	Running up West Street	09:59 WTC2 collapse	1	1	0	0	0	0	0	0	0	0	0	0	0	0
28	At incident command post on West Street	09:59 WTC2 collapse	1	1	0	0	0	0	0	0	0	0	0	0	0	0
34	WTC1 operations command post in the lobby	09:59 WTC2 collapse	[illegible]	0	0	0	0	1	0	0	0	0	0	0	0	0
36	Near WTC1 command post on the street	09:59 WTC2 collapse	1	1	0	0	0	0	0	0	0	0	0	0	0	0
44	Lobby WTC1, operations command post	09:59 WTC2 collapse	1	1	0	0	0	0	0	0	0	0	0	0	0	0
47	Stairwell WTC1, about floor 30	09:59 WTC2 collapse	1	0	0	0	0	0	0	0	0	0	0	0	0	0
55	At incident command post on West Street	09:59 WTC2 collapse	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0
59	In the streets 1 block from Towers	09:59 WTC2 collapse	1	0	0	0	0	0	0	0	0	0	0	0	0	0
37	In the street within the dust cloud	10:05 just after WTC2 collapse	1	0	0	0	0	0	0	0	0	0	0	0	0	0
48	In garage next to WTC1 incident command post	10:05 just after WTC2 collapse	0	0	0	0	0	1	0	0	0	0	0	0	0	0
56	In garage next to WTC1 incident command post	10:05 just after WTC2 collapse	0	0	0	0	0	1	0	0	0	0	0	0	0	0
16	In a building trying to get round debris that is blocking	10:17 just before collapse of WTC1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
6	Lobby WTC1	10:20 just before collapse of WTC1	[illegible]	1	0	0	0	0	0	0	0	0	0	0	0	0
7	Outside WTC1	10:20 just before collapse of WTC1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
19	At incident command post on West Street	10:29 WTC1 collapse	1	0	0	0	0	0	0	0	0	0	0	0	0	0
31	In the street, buried under rubble	10:29 WTC1 collapse	0	1	0	0	0	0	0	0	0	0	0	0	0	0
46	In the streets	10:29 WTC1 collapse	1	0	0	0	0	0	0	0	0	0	0	0	0	0
57	In the streets	10:29 WTC1 collapse	1	0	0	0	0	0	0	0	0	0	0	0	0	0
50	In the streets	10:31 just after WTC1 collapse	0	1	0	0	0	0	0	0	0	0	0	0	0	0
41	In the streets	10:45 after WTC1 collapsed	0	0	0	1	0	0	0	0	0	0	0	0	0	0
42	In the streets	10:45 after WTC1 collapsed	0	0	0	0	0	0	0	0	0	0	1	0	0	0
38	Arrived after both towers collapsed	11:25	0	0	1	0	0	0	0	0	0	0	0	0	0	0

Table C2 - Sensemaking challenges matched against 9/11 timeline (part 2 of 2)

Appendix C3 –- Sensemaking cue types and activity types in the 9/11 study

Sensemaking cue types	
Direct cues	**Indirect cues**
Knowledge - fire domain specific (Fire behaviour; structural stability; health risk)	**Audible cues** (Falling objects; location and direction of sound)
Knowledge objects - Command and Control (Command board; means of communication)	**Command and control** (Current command post location; command structure; assignments; primary efforts: evacuation, save life)
Knowledge - procedural (Communication structure; incident location specific; dealing with incident type)	**Explanations and assumptions** (Assumption; up-dated assumption; Initial explanation; up-dated explanation; alternative explanation; contradiction; estimation; expectation; scenario)
Knowledge - local (Building layout; current position of resources; landmark and object location; last known location; location specific arrangements; street size and parking)	**Building state** (Building structure; damage type, location and extent; floor conditions; structural stability; collapse; collapse trajectory)
Experience (Experience from past incidents; Experience of non-fire fighting context as analogy)	**Smoke and flames** (Fire burning and smoke characteristics; scale; location; speed; heat)
Sources of information (Control center; radio communication; situation up-date; briefing)	**Knowledge objects** (Command board; means of communication)
Audible cues (Roaring, exploding sound; plane sound; voices; falling objects)	**Knowledge - local** (Building layout; current position of resources; landmark and object location; last known location; location specific arrangements;)
	Knowledge (Most current)
	Options (Available options; eliminated option; unsatisfactory option)
	Resources - equipment and manpower (Requirement; mobilised; capabilities; availability; usability)
	Resources - people condition (Injured, missing, deteriorating)
	Safety and hazard (Hazard zone; Safe zone; safety distance; originating from people; debris (falling, on the ground, quantity))
	Situation dynamics (Increase; decrease)
	Sources of information (Colleagues; facial expression; control center; radio communication; TV; civilians; commander in charge; field communications; Multiagency (ambulance, law enforcement, emergency management); situation up-date; briefing; specialist advice)
	Surrounding area (Terrain layout; distances; space available)

Table C3a - Sensemaking cue types and categories found in the 9/11 study

Sensemaking activity types	
Activities to create cues	**Activities to use cues**
Information collection (Purposeful and specific, as you go along, reconnaissance)	**Deliberating** (Hypothesising, inference, explanation check, explanation comparison, plausibility check, considering alternatives)
Using senses (Observation, listening, feeling)	**Assessing** (Risk assessment, re-assessment, comparison activity, checking assumptions)
	Trial and error (Trying out options)
	Mental projection (Visualisation and projection, anticipating problems, tracing steps)

Table C3b - Sensemaking activity types and categories found in the 9/11 study

Appendix C4– Descriptive cue types

Cue types		
Cue type	**Frequency (Total=461)**	**%**
Indirect cue	56	12.15
Multiple cue	49	10.63
Mental vehicle	46	9.98
Direct cue	43	9.33
Up-dated cue	35	7.59
Action cue	30	6.51
Unsatisfactory cue	29	6.29
Complimentary cue	28	6.07
Non-definitive cue	28	6.07
Information source cue	27	5.86
Context changing cue	22	4.77
Confirmatory cue	19	4.12
Cue chain	18	3.90
Alternative cue	17	3.69
Single cue	14	3.04
Back-up cue	0	0
Cue composite	0	0

Table C4 – Descriptive cue types in the 9/11 study

Action cues are insights gained during the sensemaking process which trigger an action. The action is based on the insight.
Alternative cue: when used cues do not prove to be useful or do not advance sensemaking, people require an alternative cue.
Complimentary cue: when a single cue is not enough but an additional cue is sought or used; might be obtained passively.
Confirmatory cue: when there is a requirement to confirm e.g. an assumption, explanation or information. In these instances confirmatory cues can be found in the sensemaking process.
Context changing cue: When an insight is gained it might change the sensemaking context, e.g. from ambiguity to response uncertainty. Alternatively, sensemaking context changes occur when facts are observed or explanation formed but their meaning is not yet clear, one is confronted with new cues, a situational development, ambiguous information.
Cue chains are parts of a sensemaking process where the same process is repeated again and again, using one cue after another in a batch like sequence.
Information source cues are objects, people or organisational units that can provide information.
Mental vehicle: The cues that people used in the sensemaking episodes were not externalised in the sense of writing them down (with the exception of the information on the command board). Assumptions, explanations, plans and assessment were formed, changed and up-dated and held in mind. Thus, to describe the difference between cues that are externalised and held in mind, the cue type “mental vehicle” was created.
Multiple cues: Sometimes a single cue is not enough to start a sensemaking activity but multiple inputs are required. Likewise, multiple cues might be the outcome of an activity.
Non-definitive cue: A cue that is not confirmed, of undefined quality, vague or only an initial insight that requires improvement is non-definitive.
Single cue: Sometimes people seem to use only one cue in a sensemaking activity. However, if there is a cue chain, i.e. it might consist of many single cues that are used in a row.
Unsatisfactory cue: Insights can be unsatisfactory cues when they represent an undesirable outcome, e.g. of a risk or option assessment. Implausible explanations and insufficient, unconfirmed information are also unsatisfactory.
Up-dated cue: an assumption, explanation or current understanding (mental vehicle cue) of a situation was up-dated using new, complimentary and confirmatory cues.

Appendix D1- Levels of understanding - Level 0

The following Table D1a shows details on properties, activities and abilities of the level of understanding as well as and references to episodes.

Activities and abilities related to level 0 understanding

Activities to gain understanding were the perception of cues in the environment, paying attention to them, interpret other people's reaction to a situation development and relate them to some set of cues. In the above described examples the interviewees' understanding was manifested in the ability imitate the behaviour of others, act without asking questions, meaning they trusted that the actions and instructions of others were the right ones. The latter seems more convincing since many people showed this behaviour not only a single one.

Data example

The following example in Table D1b illustrates how the levels of understanding were derived from the interview data and integrated into the process diagrams.

The example illustrates how the fire chief hears a strange noise and feels the building shaking. This leads to limited understanding that something is happening but not yet what might be happening. The sensemaking context changes to state uncertainty because it is not clear what the current state of the situation is and how it is developing. This is indicated by the chief's question of "what is this?". It follows an unsuccessful attempt to collect new data to improve understanding by waiting for a development. However, nothing happens which means that he cannot improve his understanding and he stays on level 0. In the following he comes up with several explanations for what might have happened and moves to level 1.

Understanding at this level seems to be limited to realising that there is a situational development or situation dynamics change.

The gained understanding might be expressed as ability to describe the perceived cues and ask further questions about their meaning.

The episodes demonstrate that actions are possible although one does not understand what exactly is happening in that situation. This is where we differ from Endsley's model, where cue awareness is one hierarchical level but not connected with the ability to act. However, this requires either sensegiving by others or trust in their behaviour.
The next step for the sensemaker at Level 0 of the hierarchy is to find out what might be happening to gain at least some basic understanding of the situation and find some reasons for why he is imitating the behaviour of others.

Level name	Understandin g what	Episodes	Level properties	Episode s	Activities to gain understanding	Episodes	Understanding expressed by ability to…	Episodes
Level 0 - Understandin g that something is happening	Situational development or situation dynamics change	12, 15, 29, 36, 46, 47,	Ambiguity or uncertainty or information load low is triggered	15, 36, 46, 47,	Pay attention to surroundings, noticing something unusual	12, 29, 46, 47,	Describe the perceived cue	12, 29, 46, 47,
	Potential need to act immediately	15, 46,	Expectation	46,	Perceive cues	12, 29, 36, 46, 47,	Act without asking questions	15, 36, 46,
	Categorising an event as good or bad	46	Potentially very rapid increase of situation dynamics, leaving no time to ask further questions or collect more information	36, 46,	Interpretation of actions and facial expressions of people who act in response to situational development	15, 36, 46,	Trust actions and instructions of others	15, 36, 46,
			The relevant cues might not be directly visible, but indirectly (facial expression of others, actions of others)	12, 15, 36, 46, 47,	Relate reactions of people to perceived cues	15, 36, 46,	Imitate behaviour of others	15, 36, 46,
			Cues are perceived and focused on (bracketed)	12, 29, 36, 47,			Ask further questions	12, 29, 47,
			Cues are available and it is possible to notice them	29, 36, 46, 47,				

Table D1a - Levels of understanding - level 0 – properties, activities and abilities and reference to episodes

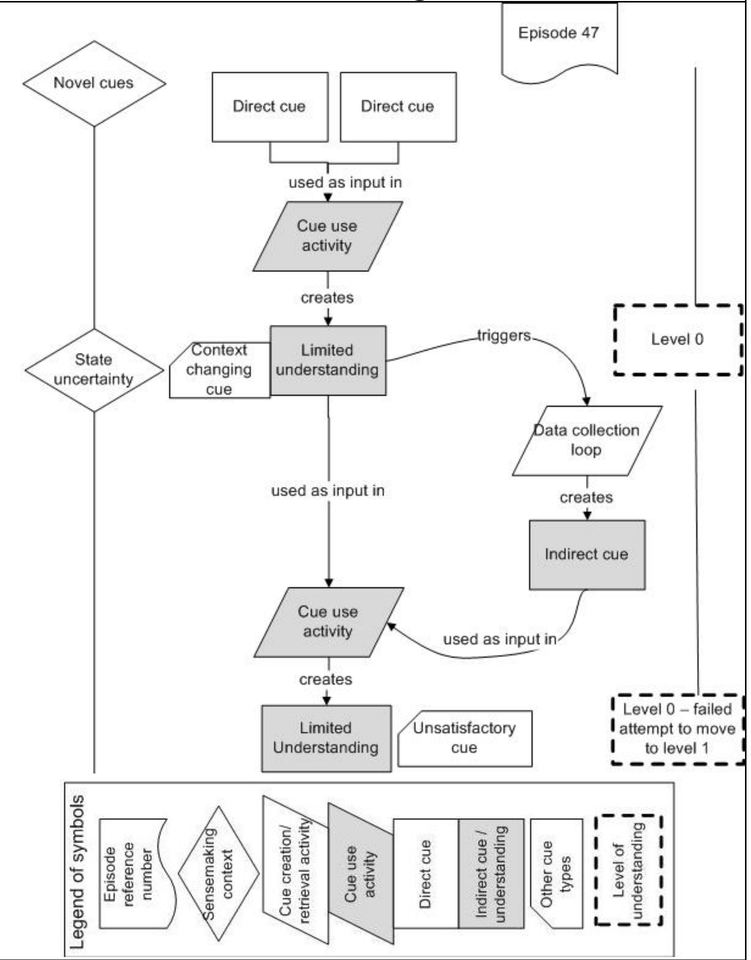
Interview data – Episode 47	Levels of understanding	Process diagram
I'm up in approximately Tower 1 somewhere in the 30s and **this rumbling starts happening**. […] We hear this noise and **everyone just freezes**, and its a rumbling, a sustained rumbling. I've heard many people describe it different ways. **To me it was indescribable, you know, it was the first time anyone heard this noise**. […] And I go into the hallway. **Everyone freezes and were trying to -- what is this? The building is shaking**. Now, this is the building that's not falling down. This was the other building. […] Building 1 is shaking. Building 2 was falling. We don't realize that. Sustained. […]. And then it stops and there's an eerie silence because, like I said, were all firemen up there and were professionals and **everyone is waiting**. So its an eerie silence. The radios stop. We have different channels. They stop and **everyone is, you know, what was that?**	Sensemaking context – novel cues Direct cue - noise Direct cue – shaking building Limited understanding – something is happening Sensemaking context – state uncertainty Data collection loop – waiting for development Limited understanding – something is happening	

Table D1b - From interview data to levels of understanding – level 0

Appendix D2- Levels of understanding - Level 1

The following Table D2a shows details on properties, activities and abilities of the level of understanding as well as and references to episodes.

Activities and abilities related to level 1 understanding

Activities to gain level 1 understanding are information collection from single or multiple sources. This includes focussing on or prioritising cues for attention, observing, and using past experience to create explanations. It might also include the comparison of several explanations and dismissing those that do not seem plausible.

Understanding at this level is characterised by the ability to describe the situation at a low detail level, speculate about the cause, state, or development of a situation, and to connect available cues in different ways to create several possible, plausible scenarios of what might be. Moreover, the ability to recognise the low quality of information or explanations and the need for additional data collection indicate understanding that one does not yet deal with facts. Converting assumptions into facts is required to progress to level 2 of the hierarchy. However, it is possible that current understanding does not progress to a higher level. This was found in the interviews when new information about possible situation developments was received, e.g. the possibility of third plane on its way. If the information cannot be confirmed despite attempts to do so, then it is still an assumption.

Also, a drop back of understanding from a higher level down to level 1 might occur. This happens, for example, when a new piece of information is received that indicates that the situation might be different to what is currently understood. If it is unverified information, then it is treated as an assumption that has to be confirmed before understanding progresses to level 2.

Data example

The following example in Table D2b illustrates how the levels of understanding were derived from the interview data and integrated into the process diagrams.

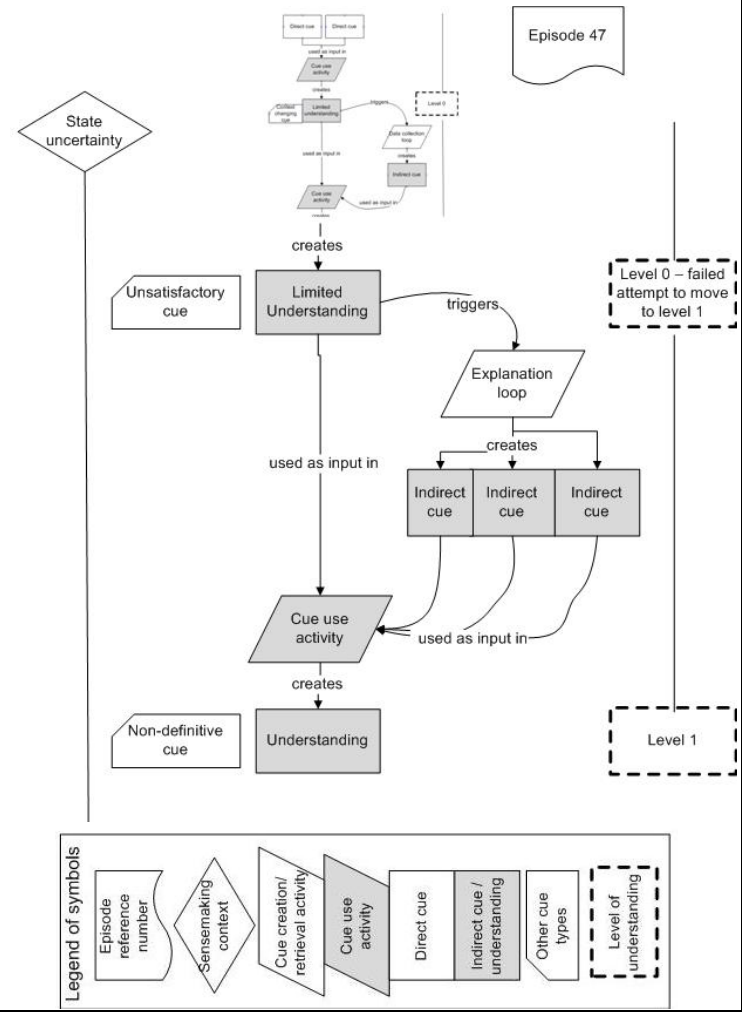
The example in Table D2b is the continuation of the episode used to illustrate level 0 understanding. The fire chief was in a stairwell of Tower 1 when he heard a rumbling noise and felt the building shaking. The example ended with an unsuccessful attempt to move to level 1. So, state uncertainty still prevails and understanding is limited. Next he enters an explanation loop and comes up with three possible explanations for the cause of the rumbling noise and the shaking building, i.e. elevators are falling, another plane and a partial collapse. This means he now has alternative explanations for what might have happened, which constitutes level 1 understanding. However, none of the explanations is confirmed, which he tries to do next to continue to level 2.

Understanding at this level is described as situation change without one noticing it and initial explanation about a cause for an event.

Appendix D2- Levels of understanding - Level 1

Level name	**Understanding what**	**Episodes**	**Level properties**	**Episodes**	**Activities to gain understanding**	**Episodes**	**Understanding expressed by ability to…**	**Episodes**
Level 1 – Understanding what might be happening	Initial explanation or assumption about what is going on	5, 10 (gap 1), 12, 13, 17, 21, 29, 33, 45 (part 1 and 2), 54	Uncertainty and ambiguity still prevail, need for confirmation,	21, 29, 33, 35, 42, 47,	Actively observing surroundings to find cues	29,	Describe a situation without much detail	4,
	Situation might have changed without noticing it	42, 47, 54,	Quality of new information is unknown, might be correct but is not believed, does not sound plausible	4, 13, 33, 45 (part 1 and 2), 54,	Passive: receiving situation up-dates, reports, using previous experience	2, 10 (gap 1), 13, 17, 21, 35, 54,	Recognise the quality of information or explanations	17, 29, 42, 45 (part 1 and 2), 54,
	Initial explanation or assumption about a cause	5, 12, 17, 20, 29, 33, 35, 47, 47 (part 2), 51,	Unverified information, assumptions, initial explanations, expectations, hypotheses, speculation, outdated information	2, 4, 12, 17, 20, 21, 29, 33, 35, 42, 45 (part 1 and 2), 47, 47 (part 2), 51, 54,	Make connections between cues (speculation)	4, 5, 12, 17, 20, 33, 35, 47, 51,	Recognise the need for confirmation or additional data collection	4, 5, 10 (gap 1), 12, 13, 17, 21, 29, 33, 35, 42, 45 (part 1 and 2), 47, 54,
	Assumed current state of operation, resource state, location	2, 4, 42,	Cause, effect, consequences of a situation are yet unknown	5, 12, 17, 29, 42, 47,	Focus on or prioritise cues for attention	29, 45 (part 1 and 2), 54,	Recognise that we are not yet dealing with facts	4, 42, 45 (part 1 + 2), 47, 47 (part 2), 51
			Situational state, risk to operation and life, nature of incident, state of operation	5, 21, 42,	Collection of pieces of information from single or multiple sources	4, 45 (part 1 and 2), 54,	Speculating about cause or development of a situation	2, 5, 12, 17, 20, 29, 33, 35, 47, 47 (part 2), 51,
			Framing of problem space	4, 10 (gap 1), 45 (part 1 and 2), 47, 54,	(Using past experience to) create plausible explanation	33, 42, 47, 47 (part 2),	Creating plausible explanations how cues are connected; inference	17, 33, 47, 51,
			Assumption used as substitute for facts, as new or more information cannot be obtained	2, 33, 47 (part 2), 51,	Comparing own explanation to other information to dismiss or confirm either one as more plausible	33, 54		

Table D2a - Levels of understanding - level 1 – properties, activities and abilities and reference to episodes

<table>
<tr><th>Interview data – Episode 47</th><th>Levels of understanding</th><th>Process diagram</th></tr>
<tr>
<td>
I'm up in approximately Tower 1 somewhere in the 30s and this rumbling starts happening. […]
To me it was indescribable, you know, it was the first time anyone heard this noise. […] Everyone freezes and were trying to -- what is this? […] and everyone is waiting. So its an eerie silence. The radios stop. […] They stop and everyone is, you know, what was that?
I didn't realize that the building came down. I didn't know what that was. I'm thinking <u>maybe elevators broke loose and elevators are falling</u> through the -- you know, different things are crossing my mind. Maybe elevators. <u>Maybe another plane hit</u>.
<u>Maybe there was a collapse up above</u> and its just a partial collapse.
So I'm calling on the radio to try to find out what happened. Finally I get a response.
</td>
<td>
Level 0 understanding – something is happening
Sensemaking context – state uncertainty
Explanation loop – hypothesising
Indirect cue – Initial explanation
Indirect cue – Alternative explanation
Indirect cue – Alternative explanation
Level 1 understanding – what might have happened
Confirmation loop
</td>
<td>


</td>
</tr>
</table>

Table D2b - From interview data to levels of understanding – level 1

Appendix D3- Levels of understanding - Level 2

The following Table D3a shows details on properties, activities and abilities of the level of understanding as well as and references to episodes.

Activities and abilities related to level 2 understanding

Level 2 might be reached in two ways. First, it might be the continuation from level 1 in which case the purpose of the sensemaking process is to create new cues. It is characterised by information collection and confirmation loops. Examples from the interview data are requesting more information from control center or colleagues to confirm assumed developments. Moreover, additional cues about a situation are obtained by observation of the incident site, e.g. location and scale of fire in the building, observing the collapse trajectory of a building, or speed, direction and contents of the dust cloud filling the streets after a tower collapse.
These loops are about creating new cues and comprise the substitution of 2^{nd} hand information with higher quality information as well as comparison and up-dating of level 1 understanding with new cues. Second, level 2 can be the entry level of the hierarchy. This is the case when an event is observed with your own eyes, there is no doubt about what is happening and there is no need for lengthy interpretation because the meaning of the situation is clear and unambiguous. If I see a building on fire, there is no doubt that this is the case. If a building is collapsing, there is no doubt about it.

The most important ability related to level 2 is to modify the so far existing understanding, coming from level 0 and 1.There also seems to be the ability to evaluate the quality of current understanding and determine if more or different cues are required, afford time for additional data collection and identify high quality information sources.

Data example

The following example in Table D3b illustrates how the levels of understanding were derived from the interview data and integrated into the process diagrams.

The example in shows how the interviewee receives novel information from his colleague and creates several explanations of what happened. Level 1 understanding is gained. However, this changes the context to ambiguity because it is not clear which explanation is the right one. He enters a first confirmation loop by going to the press office where he sees on TV what is going on, i.e. reaches level 2 understanding. Although the ambiguity is resolved now he enters a data collection loop to see the event for himself to update his understanding, i.e. level 2 improved.

Appendix D3- Levels of understanding - Level 2

Level name	**Understanding what**	**Episodes**	**Level properties**	**Episodes**	**Activities to gain understanding**	**Episodes**	**Understanding expressed by ability to…**	**Episodes**
Level 2 - What is happening	Actual current state of the situation	1, 3, 8, 9, 10 (gap 1), 11, 13, 14, 15, 16, 17, 18, 20 (part 1), 21, 22, 23, 25, 27, 28 (part 1), 29 (part 1), 30, 32, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44 (part 1 and 2), 44 (part 3), 49, 51, 53, 54,	Ambiguity and state uncertainty are reduced or resolved, plausible explanation is found	3, 5, 10 (gap 2), 12, 13, 17, 25, 28 (part 2), 29 (part 1), 29 (part 2 and 3), 30, 33, 35, 41, 42, 47,	Sensemaking process is characterised by information collection, confirmation and explanation loops	3, 5, 8, 10 (gap 1), 10 (gap 2), 12, 15, 17, 21, 21 (impr), 22 (impr), 23, 28 (part 2), 29 (part 1), 29 (part 2 and 3), 30, 32, 35, 36, 38, 40, 41, 42, 47, 53,	To afford time for additional data collection and situation analysis	5, 8, 28 (part 2), 35, 36, 38, 40, 53,
	What caused the current state	17, 19, 20 (part 1), 29 (part 1), 35, 44 (part 1 and 2), 44 (part 3), 47,	Effect uncertainty as new property of the situation	1, 7, 9, 11, 23, 25, 27, 39,	Activities to create new cues that are required but are not available	13, 30, 47, 53,	Infer what cues and actions are required for confirmation	10 (gap 1), 13, 17, 21, 22 (impr), 47, 53,
	Current, ongoing development of the situation (might be new aspect of the same situation)	3, 7, 10 (gap 2), 18, 20 (part 2), 21 (impr), 22 (impr), 25, 25 (part 2), 29 (part 2 and 3), 30, 36, 38, 40, 42, 53,	Established facts	1, 3, 8, 9, 10 (gap 1), 10 (gap 2), 11, 12, 13, 17, 18, 20 (part 1), 21, 21 (impr), 22, 22 (impr), 25 (part 2), 27, 28 (part 1), 29 (part 1), 29 (part 2 and 3), 35, 38, 39, 40, 41, 43, 44 (part 1 and 2), 47, 51, 53,	Unequivocal meaning assigned to observed of cues (direct understanding)	1, 5, 9, 10 (gap 1), 11, 12, 16, 17, 18, 19, 20 (part 2), 21 (impr), 22, 22 (impr), 25, 27, 28 (part 1), 29 (part 1), 29 (part 2 and 3), 35, 36, 37, 38, 39, 40, 41, 43, 44 (part 1 and 2), 44 (part 3), 49, 51,	Modify current understanding by using new cues in comparison activity	3, 8, 10 (gap 1), 10 (gap 2), 12, 13, 15, 17, 18, 19, 20 (part 1), 20 (part 2), 21 (impr), 22 (impr), 25 (part 2), 28 (part 2), 29 (part 1), 29 (part 2 and 3), 30, 32, 33, 35, 40, 42, 47, 53,
	Severity of situation	5, 8, 25 (part 2), 28 (part 2), 32, 38, 49,	High confidence level about correctness of established situation state, fairly good idea of something	3, 9, 12, 21, 23, 28 (part 2), 30, 33, 37, 40, 41, 44 (part 3), 47, 49, 53, 54,	Comparison of new cues with level 2 understanding (support, up-date or disprove)	3, 8, 10 (gap 2), 12, 13, 19, 21 (impr), 22 (impr), 23, 28 (part 2), 29 (part 2 and 3), 30, 32, 38, 40, 42, 47, 53,	Identify sources that can provide high quality information	21, 41,

	Real explanation for noticed cues (as opposed to assumption)	12, 19, 20 (part 1), 29 (part 1), 33, 47,	Assumptions are converted into verified facts; earlier projection of consequences is now confirmed as true	10 (gap 1), 20 (part 1), 21, 25 (part 2), 29 (part 1), 35, 42, 47,	2nd hand information is substituted by 1st hand information or observation	13, 17, 21 (impr), 29 (part 2 and 3), 35, 36,	Evaluate the quality of current understanding	3, 10 (gap 1), 21, 33, 47, 47 (part 2),
			Information quality is high	41, 47,	Forming an approximate mental picture	23, 32, 42,	Follow orders	5,
			Incident type, cause of incident, incident scale and severity are established facts	8, 10 (gap 1), 10 (gap 2), 17, 19, 22, 22 (impr), 28 (part 1), 29 (part 1), 29 (part 2 and 3), 32, 40, 49,	Interpretation (connecting cues) --> results in treating an assumption as fact or disregarding it	7, 12, 17, 19, 20 (part 1), 42, 54,	Connect cues	7,8, 11, 12, 16, 19, 23, 25, 25 (part 2), 29 (part 1), 29 (part 2 and 3), 32, 37, 40, 42, 47, 49, 51, 53,
			Possibility that understanding is based on misinterpretation of cues, what seems as fact is in reality no fact ; expectation is treated as fact	7, 15, 19, 25, 37, 54,	Alternative explanation(s) for a cause (speculation, i.e. level 1 within level 2)	15, 20 (part 1), 47,	Use analogies to describe situation	20 (part 2),
			Level 2 might be entry level for understanding if the meaning of cues is unequivocal, i.e. direct observation of facts	1, 16, 18, 20 (part 2), 22, 22 (impr), 25 (part 2), 27, 28 (part 1), 36, 38, 39, 40, 41, 43, 44 (part 3), 49, 51,	Passive: receiving situation up-dates, reports, obtaining order from commander, experience, expectation	5, 22, 22 (impr), 29 (part 1), 29 (part 2 and 3), 33, 40, 47, 51, 53, 54,	Take corrective action based on current understanding	38,
			Facts of situation are clear but are too implausible to be believed	14,	Comparing new cues with earlier understanding from level 3 or level 1 explanations	25 (part 2), 33, 35, 42,	Use experience to come up with an explanation	54,

Table D3a - Levels of understanding - level 2 – properties, activities and abilities and reference to episodes

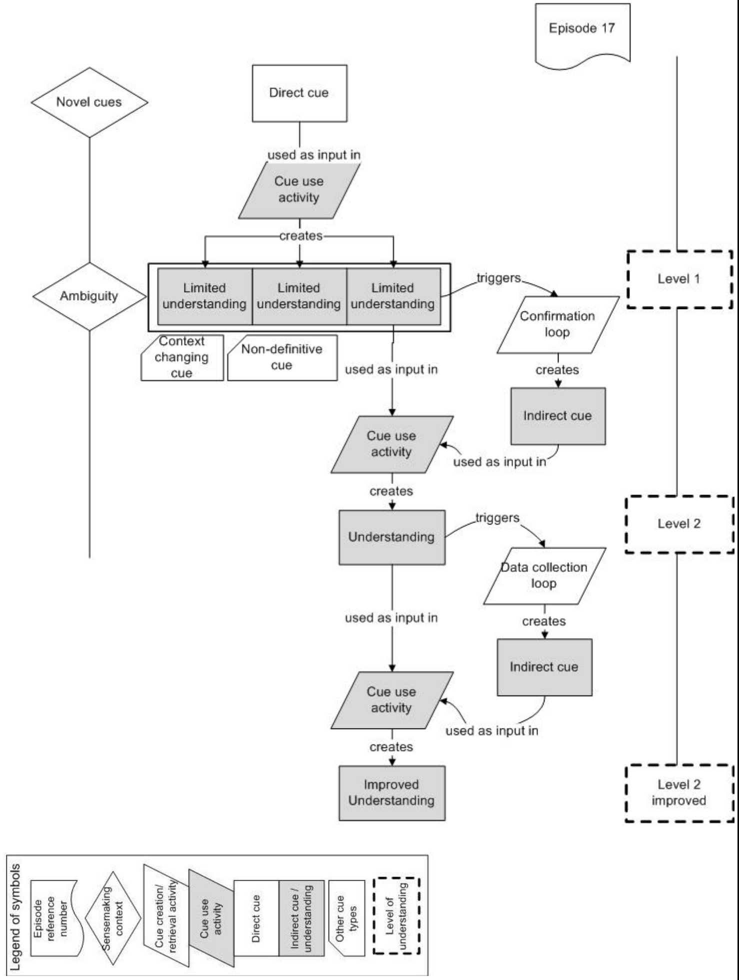
Interview data – Episode 17	Levels of understanding	Process diagram
I was in the office that morning. If I refer to the time line now I received, it was right after -- I guess as soon as the plane hit. Someone came into the office and just **told me that a plane had hit** the World Trade tower. I **assumed it was a small plane**, an **aviation accident**, and **I thought he was kidding** also. I went out to the main press office to look at it. I think by then the **TV was on and it showed it** and **I could see the tower**. I grabbed the car. Mine was in the shop, so I borrowed one of our spare vehicles and just responded out. I grabbed a vehicle and went downstairs and responded out to it, figuring it was a press event, obviously, of magnitude.	Sensemaking context – novel cues Direct cue - information Indirect cue – Assumption Indirect cue – Alternative explanation Indirect cue – Alternative explanation Sensemaking context – Ambiguity Level 1 understanding – what might be happening Confirmation loop – info collection Level 2 understanding – what is happening Data collection loop – observation Level 2 understanding improved	

Table D3b - From interview data to levels of understanding – level 2

Appendix D4- Levels of understanding - Level 3

The following Table D4a shows details on properties, activities and abilities of the level of understanding as well as and references to episodes.

Activities and abilities related to level 3 understanding

The main activities to gain level 3 understanding were risk assessment, mental projection of situation development, comparison of current and projected future state, relating elements to each other to see the effect. Understanding at this level is manifested in the abilities to apply trained measures to avoid or respond to risks, evaluate outcomes of a mental projection and assessment in terms of gravity, impact, probability and immediacy. Moreover, the ability to recognise and define the need as well as goals to generate courses of action was identified.

Although effect uncertainty is reduced at this level it was found that the sensemaking process continues further because the situational context changed to response uncertainty. Thus, what needs to be understood next is what options for action are available at all.

Data example

The following example in Table D4b illustrates how the levels of understanding were derived from the interview data and integrated into the process diagrams.

The example shows how multiple novel cues are observed. They are the facts that describe the situation, i.e. level 2 understanding. A descriptor was used to indicate the sensemaking context changes to effect uncertainty (this is what the next stage of the process is about). Meaning of the cues is created by relating them together in a risk assessment, resulting in the insight of possible consequences, i.e. the command post might be hit by falling debris. Once theses consequences are understood (= level 3), the command post is moved further away.

What is understood at this level is at level 3 are implications of situational development expressed as projected future state of a situation and the implication of that potential development on current operations.

Appendix D4- Levels of understanding - Level 3

Level name	Understanding what	Episodes	Level properties	Episodes	Activities to gain understanding	Episodes	Understanding expressed by ability to…	Episodes
Level 3 – Understanding consequences	Implications of current situational state or in relation to oneself	1, 7, 15 (episode 1), 15 (episode 2), 25, 28, 34, 36, 37, 44,	Reduction of effect uncertainty	1, 6, 7, 9, 11, 15 (episode 1), 19, 23, 25, 27, 28, 39,	Mental projection of object trajectory, situation development, worst case	1, 6, 11, 15 (episode 1), 19, 20, 23, 25, 34, 36, 47,	Recognise the need for options of courses of action	1, 6,
	Change of situation dynamics	34, 44,	Potential context change to response uncertainty	1, 16, 34, 36, 43, 44,	attention to surroundings,	34, 36, 39,	Define needs for action (shelter)	7, 28, 44,
	Implications of development expressed as projected future state of a situation	1, 6, 7, 11, 15 (episode 1), 15 (episode 2), 19, 20, 28, 34, 36, 37, 39, 44,	Gravity of effect, immediacy of effect à indication when action needs to be taken	15 (episode 1), 15 (episode 2), 20, 25, 34, 36, 37, 44, 47,	Use of knowledge about fire behaviour and risks to derive consequences; combine knowledge with other cues	34, 37, 43, 44, 49,	Recognising urgent requirement for taking decision or formulating course of action	7, 9, 11, 27, 34, 36, 44,
	Implication of projected or potential situation development on current operations	9, 23, 27, 39, 43, 49,	Understanding of effects from effects	6, 7, 11, 15 (episode 2), 20, 44,	relating two elements together to investigate effect of one on the other (smoke on breathing,)	16, 27, 34, 37,	Mentally generate scenarios or project current state into the future	6, 11, 15 (episode 1), 15 (episode 2), 19, 20, 23, 34, 36, 39, 47,
	If situation is aligned with one's goal or not	16,	Understanding of risk from objects, smoke, fire, explosion, dust	6, 7, 27, 34, 36, 37, 39,	analyse surroundings;	15 (episode 1), 23, 25, 34, 36, 39,	Formulate goals that are relevant for option generation	6, 16, 44,
	Potential implication of a past event on operations	47,	Risks associated with the situation are understood	1, 6, 7, 9, 11, 27, 28, 34, 36, 37, 39,	compare current and projected future state	11, 15 (episode 2), 20, 34,	Apply training to avoid or respond directly to a risk	9, 11, 27, 28, 37, 39,
			Effect of situation on personal health and safety	6, 7, 15 (episode 1), 25, 28, 34, 37, 44,	Use of analogies and previous experiences to test potential effects (jumpers)	20, 49,	Evaluate outcomes of assessment for gravity, impact, probability	1, 9, 11, 15 (episode 1), 15 (episode 2), 23, 25, 34, 36, 37, 39, 44, 49,
			Consequence immediately rules out an option for course of action	43, 49,	Risk assessment	6, 7, 9, 11, 15 (episode 1), 25, 27, 28, 34, 37, 39, 44,	Generate additional cues and combine with level 2 for an assessment	20, 23, 43, 47, 49,

			Safety implications on current operations	1, 9, 11, 23, 27, 39,				
			Estimated probability of implication	49,				

Table D4a - Levels of understanding – level 3 – properties, activities and abilities and reference to episodes

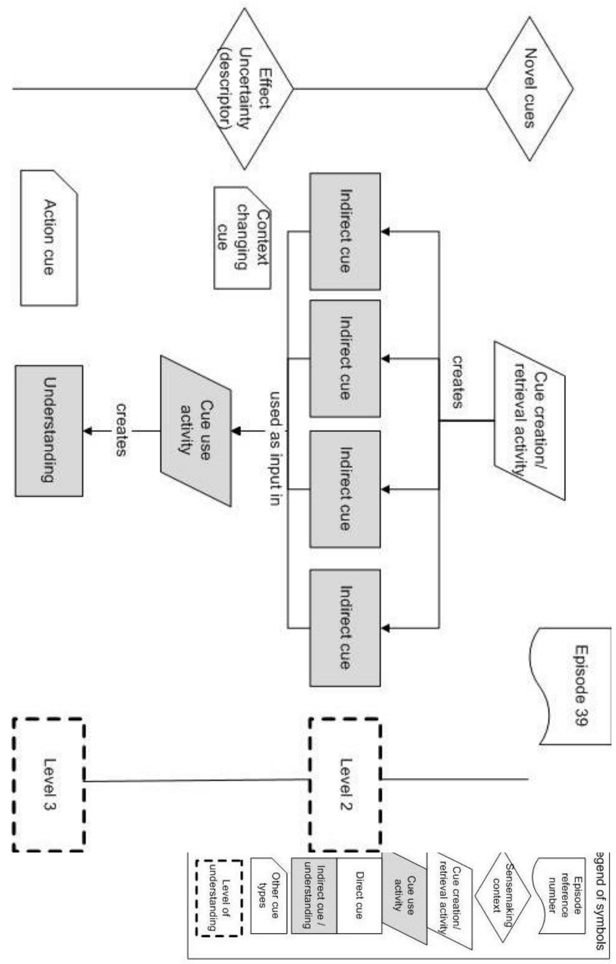
Interview data – Episode 39	Levels of understanding	Process diagram
I believe field com was in the process of setting up a **command post in the middle of West Street**, where there was an island that runs up the street,	Sensemaking context – novel cues Indirect cue – command post location	
which we felt to be too **close to the building**	Indirect cue – Safety distance	
because of **debris that was already falling** and	Indirect cue – Falling debris	
had fallen in the street and	Indirect cue – Debris on the ground Level 2 understanding – what is happening Sensemaking context – Effect uncertainty (descriptor)	
[author comment: sentence moved from above] which we **felt to be too close to the building**	Level 3 understanding - Implication	
we moved the exterior command post across West Street to the garage entrance in front of, I believe the address would be 2 World Financial Center.		

Table D4b - From interview data to levels of understanding – level 3

Appendix D5- Levels of understanding - Level 4

The following Table D5a shows details on properties, activities and abilities of the level of understanding as well as and references to episodes.

Activities and abilities related to level 2 understanding

Next to the activities of lower hierarchy levels we found that several other activities were used to reach an understanding of options. Among these were forming assumptions, creating mental scenarios (what you see yourself doing), and observation of the surroundings, which is guided by a goal that was derived from level 3. This means that understanding the implications of a situation (level 3) can create a goal that guides the search for options. For instance, the evaluation of a command post location revealed that it is not safe or people realise they are in a collapse zone. Thus, the search for options is guided by safety criteria, e.g. safety distance or shelter.

Understanding at this level is expressed as the ability to formulate search criteria (goals), relate the function of objects in the environment to search goals, confirm the existence of options, and identify the need to evaluate options. Although response uncertainty can be reduced somewhat at this level it requires evaluation at level 5 to be resolved completely.

Data example

The following example in Table D5b illustrates how the levels of understanding were derived from the interview data and integrated into the process diagrams.

The first part of the example shows how understanding progresses from level 2 to 3. The interviewee thinks that he is in a smoke area and that the smoke will have serious health consequences. Thus, he engages in trained behaviour to stay low in a smoke area. An overhears an unexpected new piece of information that he is not in a smoke area but that the cloud contains dust, i.e. it is difficult to breathe but at least one breathes no smoke. Thus, there is the potential option of really breathing without major risk. He engages in a confirmation loop and notices that he can breathe, it is air and not hot as smoke would be. This evaluation at level 5 leads to understanding that the option really exists and is viable. Initially he understands what a potential option is and that there might one option be available. After testing it at level 5 he understands that it is really existing and viable.

Appendix D5- Levels of understanding - Level 4

Level name	Understanding what	Episodes	Level properties	Episodes	Activities to gain understanding	Episodes	Understanding expressed by ability to…	Episodes
Level 4 - Option generation	What a potential option is	1, 6, 24, 26, 31 (part 1, 2 and 3), 34 (part 2), 36 (part 1, 2 and 3), 37, 44 (part 1), 44 (part 2),	Characterised by response uncertainty	1, 6, 16, 24, 26, 31 (part 1, 2 and 3), 34 (part 1 and 2), 36 (part 1, 2 and 3), 37, 43, 44 (part 1 and 2), 47, 49,	option discovery by observing the surrounding terrain (looking for shelter) and comparing object suitability for goal fulfilment	1, 31 (part 1, 2), 36 (part 1, 2 and 3), 44 (part 1),	Identify need for option evaluation	26, 31 (part 1, 2 and 3), 34 (part 1),
	What a real option is	34 (part 1), 43, 47,	Potentially no conscious generation of options if there is only one available (run away)	24, 43, 47,	Creating mental scenario (what you see yourself doing)	26, 31 (part 1, 2 and 3), 34 (part 1), 36 (part 2 and 3), 44 (part 1),	Pursue option without evaluation if time is constraining factor	34 (part 2), 44 (part 2),
	What not an option is	31 (part 1, 2), 49,	Generation of one option leads to immediate evaluation (progress to level 5), no generation of many options before evaluation observed	24, 31 (part 1, 2 and 3), 34 (part 1), 36 (part 1, 2 and 3), 44 (part 1),	Forming assumptions about what could be done	6, 24, 26, 31 (part 1, 2 and 3), 34 (part 2), 36 (part 2 and 3), 44 (part 1),	Formulate search criteria (goal)	6, 16, 24, 26, 31 (part 1, 2 and 3), 36 (part 1, 2 and 3), 37, 44 (part 1 and 2),
	Availability of an option	16, 34 (part 2), 36 (part 1, 2 and 3), 37, 44 (part 2),	A goal is guiding option generation, comparison of potential options with goal determines whether something counts as option	1, 6, 16, 24, 31 (part 1, 2), 36 (part 1, 2 and 3), 44 (part 1 and 2),	Evaluation if option really exists	34 (part 2), 37, 43, 49	Relate function of objects in the environment to the goal that is guiding option generation	1, 31 (part 1, 2 and 3), 36 (part 1, 2 and 3), 44 (part 1 and 2),
			Forming assumptions about what could be done	6, 26, 31 (part 1, 2 and 3), 36 (part 1, 2 and 3), 37, 44 (part 1),	thinking about the opposite of original subject	6,	Mentally project	26, 31 (2), 34 (part 1), 44 (part 1),

			Time constraints for option generation exists	34 (part 1 and 2), 36 (part 1, 2 and 3), 44 (part 1 and 2),	testing if consequences are real (tries to breathe, feels the air);	37,	Confirm existence of option	34 (part 2), 37,
			Option is not evaluated, option is directly acted upon	34 (part 2), 43, 44 (part 2), 47,	Option discovery by remembering previous experience	44 (part 2),	Identify option by creating a bigger picture based on assumption, procedures and situational facts	47, 49,
			Option is not in line with goal but needs to be considered when other options were ruled out or it is the lesser of 2 evils	31 (part 3),	Inference, i.e. connecting multiple cues leaves just one option	47,		
					comparing situation with response repertoire	43, 49,		
					additional data collection	1, 16, 34 (part 2),		

Table D5a - Levels of understanding – level 4 – properties, activities and abilities and reference to episodes

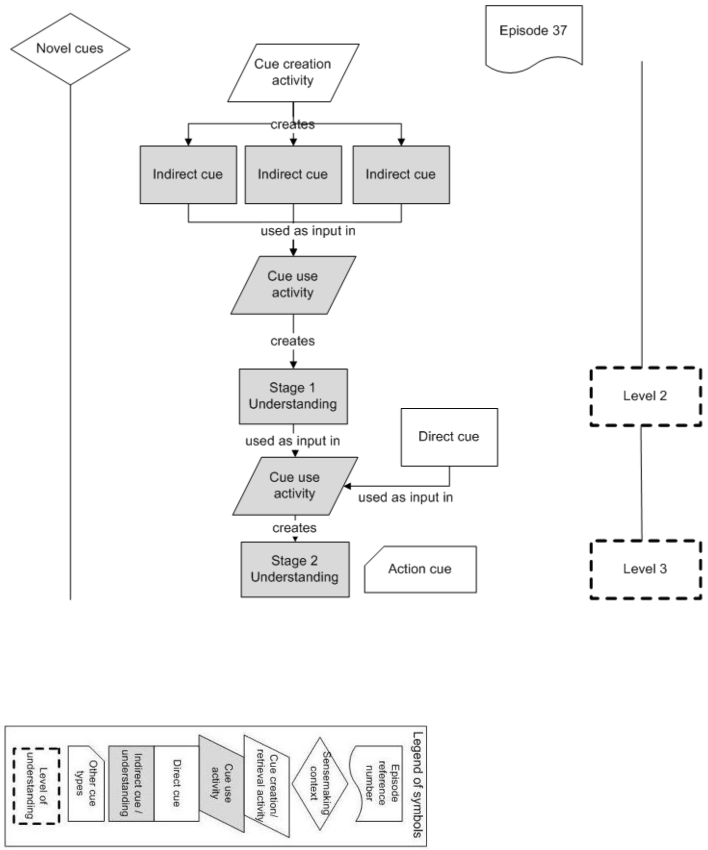
<table>
<tr><th>Interview data – Episode 37</th><th>Levels of understanding</th><th>Process diagram</th></tr>
<tr>
<td>When the black came in I thought, at first I thought that it was smoke coming down there. I saw an orange glow, I don't know where it was, a small orange glow. I believe it was to -- I was disoriented. It looked like it was to my left. I'm thinking maybe people; now I'm thinking that <u>jet fuel</u>, the <u>thick black smoke</u> and I'm down on the ground. I got my face, my teeth to the concrete at that point, completely flat, just using what I was taught, you know. Get low. At that point I figured, I kind of thought this was -- my only thought was this is where they're gonna find me on the street corner. I thought I was in -- <u>I it was in a smoke area</u>. I figured like I said it was diesel or jet fuel. It's not going to do any kind of, whatever. <u>It gets inside your lungs just like an oil burner fire.</u>

I got my face, my teeth to the concrete at that point, completely flat, just using what I was taught, you know. Get low.</td>
<td>Sensemaking context – novel cues

Indirect cue – smoke characteristic
Indirect cue – fire characteristics
Indirect cue – jet fuel

Level 2 understanding – what is happening

Direct cue – health risks
Level 3 understanding - Implication

Cue type – Action cue</td>
<td>
</td>
</tr>
</table>

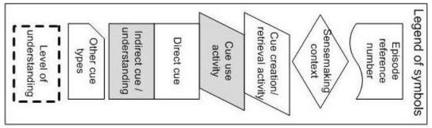
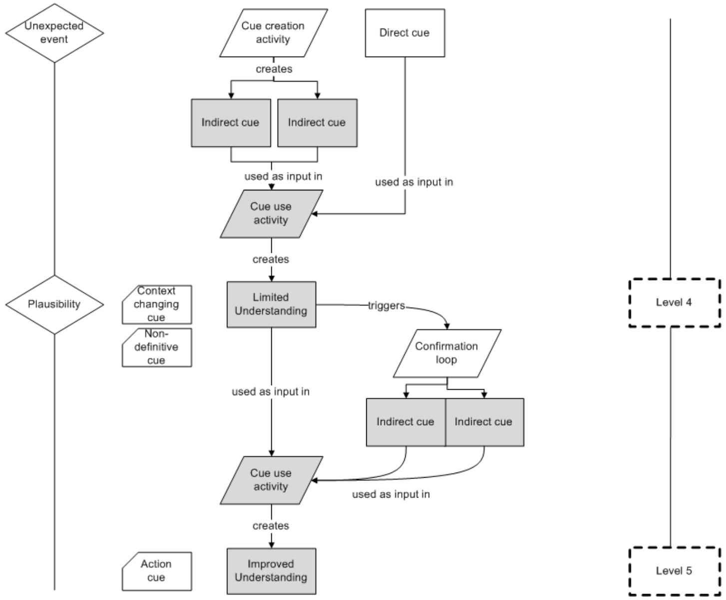
Anyway, at one point I'm down there and I'm not covering my face. I'm just breathing slowly, I'm pacing my breathing, I'm not panicking, trying to keep everything nice and calm like we are supposed to. I heard some people screaming. Some people like I can't breathe, I can't see, stuff like that. Sporadically, not a lot, very sporadically. Maybe two or three. **Somebody, which actually helped me**, I don't know who it was, after somebody said I can't breathe, somebody, I don't know which direction it came from, **screamed out don't panic or relax, relax. It's not smoke. It's just dust**. Just relax. At that point, that's when I started to realize **my mouth was filling up with like a sand ball**. All of a sudden I realized when whoever said that, now I'm starting to pay attention to my surroundings. I realized there was **no heat**, you could breathe. **Stuff was going in your mouth but it was like a cool air coming in when you breathe it**, so **I said maybe he was right**. You couldn't see, it was gritty. So at that point **I took my jacket and put my jacket around my face**,	Sensemaking context – unexpected event Direct cue – situation up-date Indirect cue – no smoke Indirect cue – objects Level 4 understanding – potential option Sensemaking context – Plausibility Confirmation loop Indirect cue – heat Indirect cue – absence of problem Level 5 understanding – Option evaluation Cue type – Action cue	 

Table D5b – From interview data to levels of understanding – level 4

Appendix D6- Levels of understanding - Level 5

The following Table D6a shows details on properties, activities and abilities of the level of understanding as well as and references to episodes.

Activities and abilities related to level 5 understanding

To gain understanding at this stage requires a set of criteria for evaluation. Evaluation activities comprise mental projection of pursuing an option, risk assessment to anticipate problems and consequences, and physically trying out a course of action. One interviewee reported how found shelter from the falling debris and the dust cloud after a tower collapse. He describes how he tries out leaning against a fence, mentally simulated what would happen when he sought cover under a car and finally chose to hide behind a brick wall because it was in line with his search criteria for a solid shelter that can withstand whatever is coming. Thus, the evaluation also includes a risk assessment because once an option is generated it might not be obvious what implications arise from pursuing it, i.e. the context is effect uncertainty. This means that level 5 also comprises activities that we have seen at level 3 (implication) but now with a focus on a course of action. The abilities that describe understanding at level 5 are formulating criteria for evaluation, integrating goals, evaluation criteria and foreseen or experienced actions, describing consequences of pursuing an option and justifying how an option leads to goal achievement. Time constraints might not allow for option evaluation, which could lead to following a course of action although it was not tested.

Data example

The following example in Table D6b illustrates how the levels of understanding were derived from the interview data and integrated into the process diagrams.

In the example the fire chief is in the lobby of a tower and based on the sudden noise and building trembling he is convinced that tower is collapsing. Level 3 is not described in the data but it is assumed that he concludes that he is in a hazard zone, otherwise he would not look for options to find a sheltered area. Option 1, i.e. going further into the lobby is found by observation of the surrounding area (=level 4) and dismissed in an evaluation, using criteria for stability (=level 5).

Option 2 is created by remembering what he has seen earlier (=level 4), i.e. the massive columns he passed on his way to the lobby. There is no description if it is evaluated but it is assumed that he does because they were earlier described as stable structure and in the evaluation of option 1 he was looking for a well supported area. Thus, these columns seem to meet his search criteria and he acts.

What is understood at this level is at level is that option 1 is not suitable because of its associated risk, whereas option 2 is viable.

Appendix D6- Levels of understanding - Level 5

Level name	**Understanding what**	**Episodes**	**Level properties**	**Episodes**	**Activities to gain understanding**	**Episodes**	**Understanding expressed by ability to…**	**Episodes**
Level 5 - Option evaluation	Suitability and viability of an option	24, 31 (part 1, 2 and 3), 34 (part 1), 36 (part 1, 2 and 3), 44,	Reduction of response uncertainty if evaluation is in favour of the option	24, 26, 31 (part 3), 36 (part 3),	Having criteria for evaluation	26, 31 (part 1, 2 and 3), 36 (part 1, 2 and 3), 44,	Justify if pursuing an option leads to goal achievement	26, 36 (part 1, 2 and 3),
	Worthiness of pursuing an option	34 (part 1), 36 (part 1, 2 and 3),	Evaluation to which degree using the option is aligned with a goal	26, 36 (part 1, 2 and 3), 44,	Assessing option against criteria	24, 26, 31 (part 1, 2 and 3), 36 (part 1, 2 and 3), 44,	Formulate criteria for evaluation	24, 31 (part 1, 2 and 3), 36 (part 1, 2 and 3), 44,
	Risk associated with option	31 (part 2 and 3), 36 (part 2), 44,	Quality differences in evaluation: trying out vs. mental scenario	36 (part 1, 2 and 3),	Mental projection of consequences of pursuing the option	24, 26, 31 (part 2), 36 (part 2),	Integrate goal, evaluation criteria and foreseen or experienced action of carrying out the option	26, 31 (part 1, 2 and 3), 34 (part 1), 36 (part 1, 2 and 3), 44,
	Consequences of carrying out an option	26, 31 (part 2),	Response uncertainty continues when option is ruled out, drop to level 4	31 (part 1, 2), 34 (part 1), 36 (part 1, 2), 44,	Mental projection of pursuing an option to decide whether it is tried for real	26, 31 (part 2), 34 (part 1), 36 (part 2 and 3),	Mentally simulate course of action	24, 26, 31 (part 2), 36 (part 2 and 3), 44,
	If option can be carried out	31 (part 1),			Physically trying out option to generate feedback	36 (part 1),	Describe consequences of a course of action	26, 36 (part 2),
					Comparing 2 options	31 (part 3),		
					Risk assessment, problem anticipation	31 (part 1, 2 and 3), 34 (part 1), 36 (part 2), 44,		

Table D6a - Levels of understanding – level 5 – properties, activities and abilities and reference to episodes

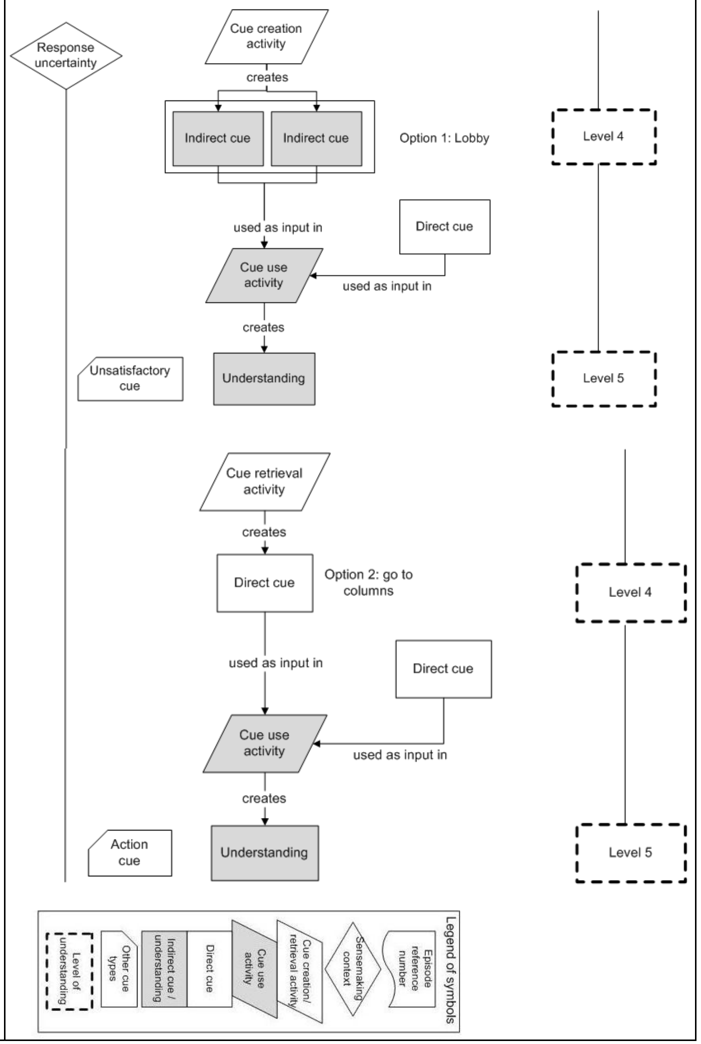
Interview data – Episode 44	Levels of understanding	Process diagram
I'm walking through, and I could see these concrete columns, big concrete columns, three feet, maybe even larger than that, maybe up to four feet in diameter. I just made note of it. Then [..] there's a circular area. It's like a rotunda. I remember the ceiling was higher there. The columns were all around that, all around the walls. Again, I said they weren't there in '93, those towers. I just said in the back of my mind they must have put those things in when they rebuilt this place, because that's about the area where the bomb went off. […] then -- the columns ended, and just before you walked into the lobby – […] and I could see the glass windows, see the high ceiling of the lobby. […] at that exact moment I can feel -- or hear the noise first. I hear a noise. Right after that noise, you could feel the building start to shudder, tremble, under your feet. Somebody said to me, "What's going on?" I said, "What's going on? […] "I actually said, "[…] This goddamn building is coming down."	Level 2 understanding – what is happening Level 3 understanding - Implication Sensemaking context – response uncertainty	
I looked real quick forward. I didn't like that option because it was a **<u>big, high lobby</u>**, a **<u>lot of glass</u>**. I figured it was **<u>not that well supported</u>**.	Indirect cue – Terrain layout Indirect cue – Structural stability Level 4 understanding – Option 1 Direct cue – stability criteria Cue type – Unsatisfactory cue Level 5 understanding – Option ruled out	
I **<u>remember seeing those columns</u>**. Whoever was next to me -- I thought it was Telesca, but it ended up being Myers, Brian Myers. He said, "Where are we going?" I turned and said, "**<u>We're going back to those columns</u>**." I remember taking a few steps and trying to run, and you're either thrown or blown off your feet. I remember I ended up my face was right up against the wall, a column was right near my left shoulder, a big column. That's it.	Direct cue – Option 2 Level 4 understanding – Option 2 Direct cue – stability criteria Level 5 understanding – Option approved Cue type – Action cue	

Table D6b – From interview data to levels of understanding – level 5

Appendix D7- Levels of understanding - Level 6

The following Table D7 shows details on properties, activities and abilities of the level of understanding as well as and references to episodes.

Activities and abilities related to level 6 understanding

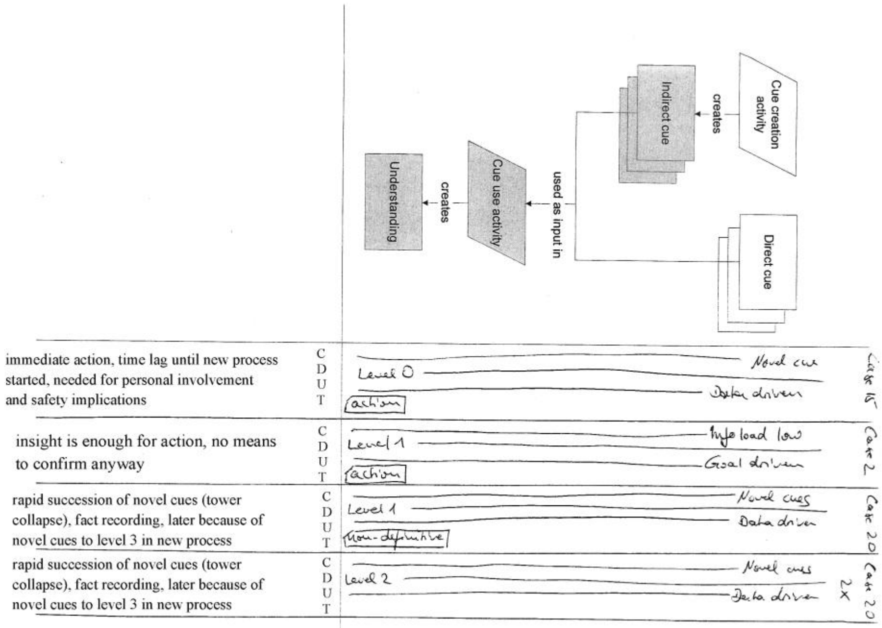
The activities used for performance evaluation are physically trying out an option, observing, listening and feeling to generate new cues that indicate performance. Understanding at level 6 might be expressed as ability to understand if action has the desired effect that was anticipated, i.e. goal can be achieved, understand the progress one is making in achieving a goal and understanding what cues indicate achievement.

Appendix D7- Levels of understanding - Level 6

Level name	**Understanding what**	**Episodes**	**Level properties**	**Episodes**	**Activities to gain understanding**	**Episodes**	**Understanding expressed by ability to…**	**Episodes**
Level 6 - Achievement testing	If the option works	24, 48, 56	Rapid succession of sensing, acting cycles	24, 48, 56	Physically trying out an option that was generated and evaluated earlier	24, 48, 56	Understand if action has the desired effect that was anticipated, i.e. goal can be achieved	24, 48, 56
	Partial achievement	48, 56	Characterised by performance uncertainty	24, 48, 56	Observing, listening and feeling to generate new cues	48, 56	Understand the progress one is making in achieving a goal	24, 48, 56
			Creation of feedback	24, 48, 56	Trying to find indicators that course of action delivers desired results	48, 56	Understanding what cues indicate achievement	24, 48, 56

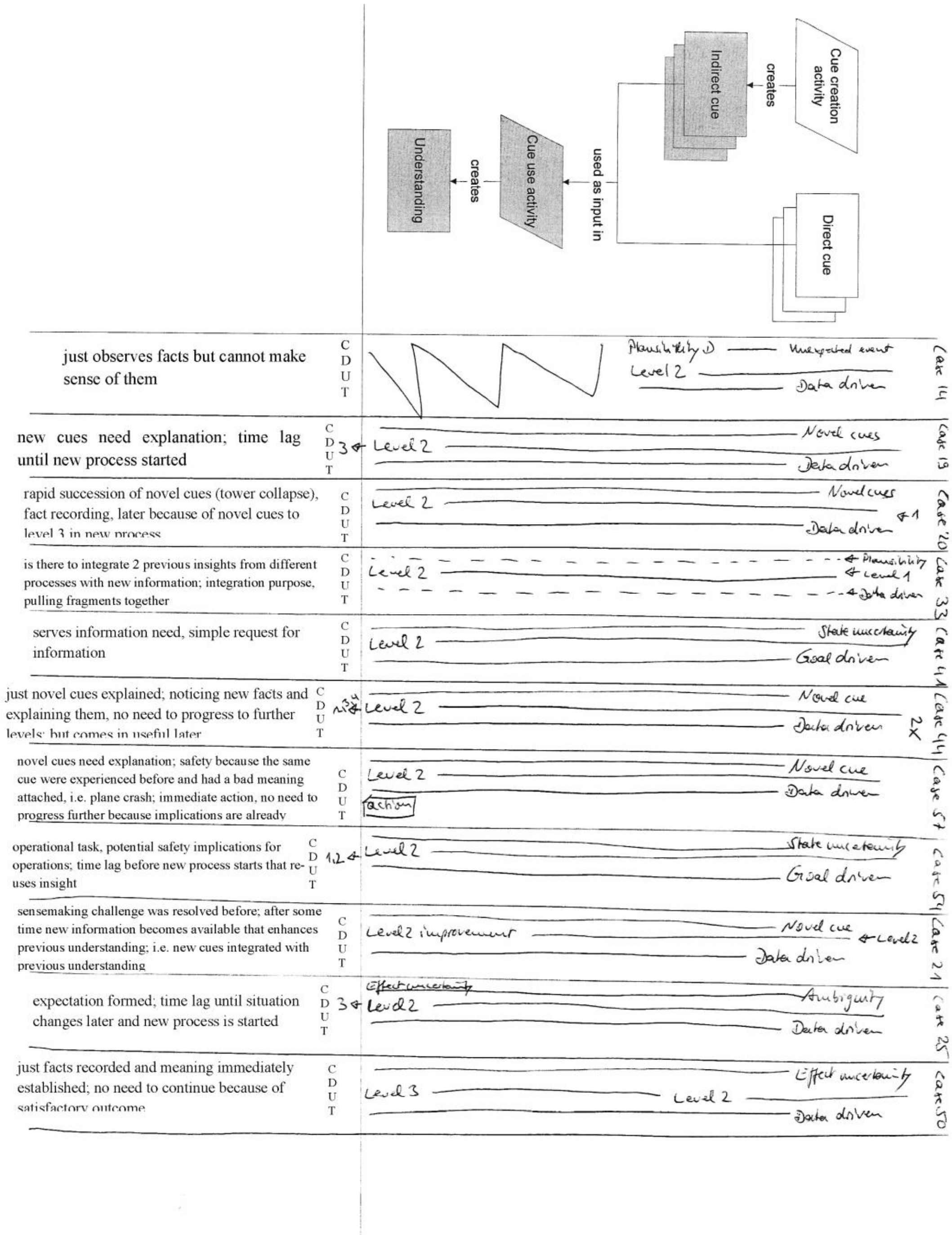
Table D7 - Levels of understanding – level 6 – properties, activities and abilities and reference to episodes

Appendix D8 - Analysis of underlying mechanisms in process variations



C = Sensemaking context D = Data/goal driven
U = Level of understanding T = Cue type

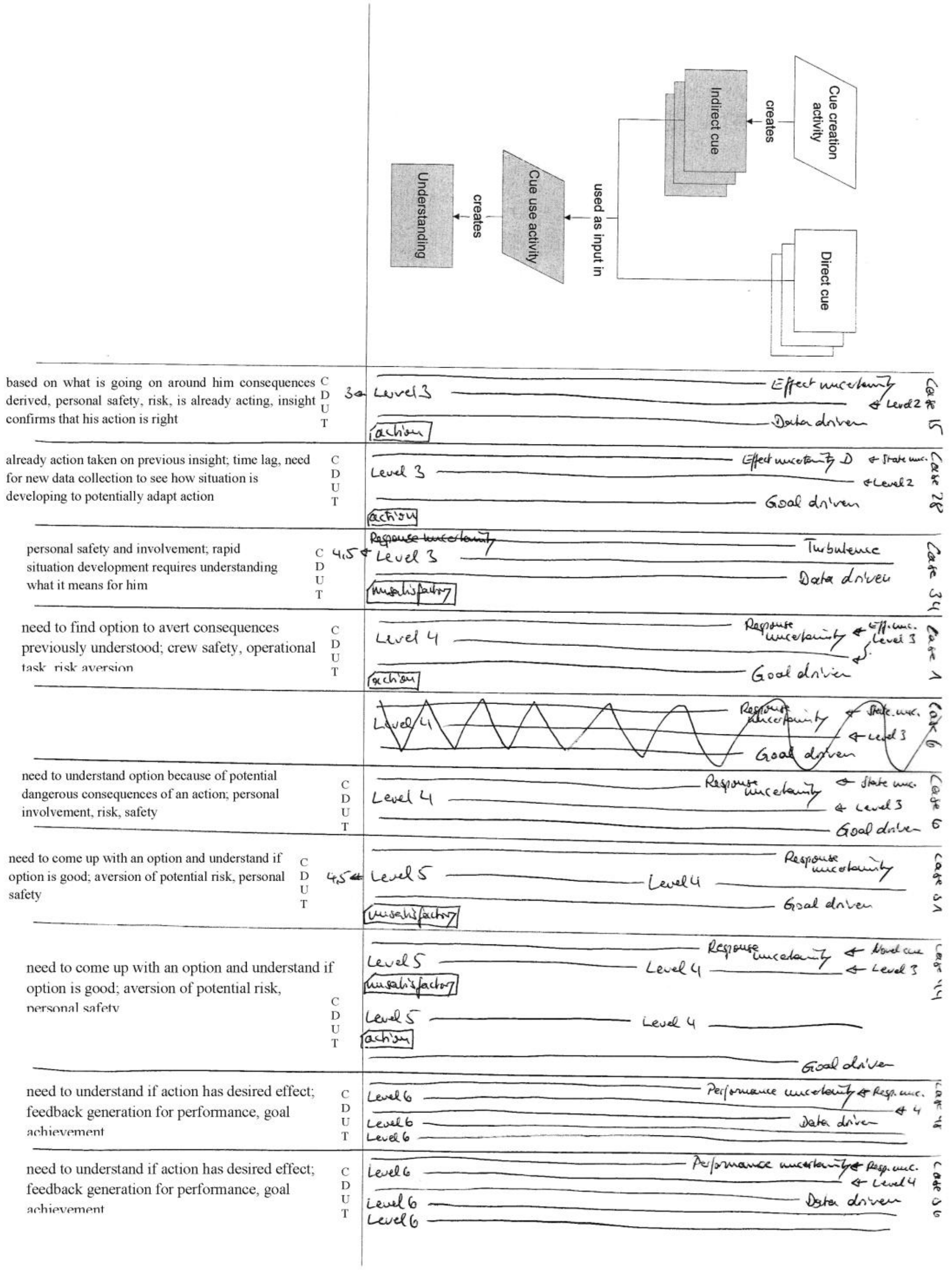
Figure D8a – Analysis of four mechanisms in the simple process



C = Sensemaking context D = Data/goal driven

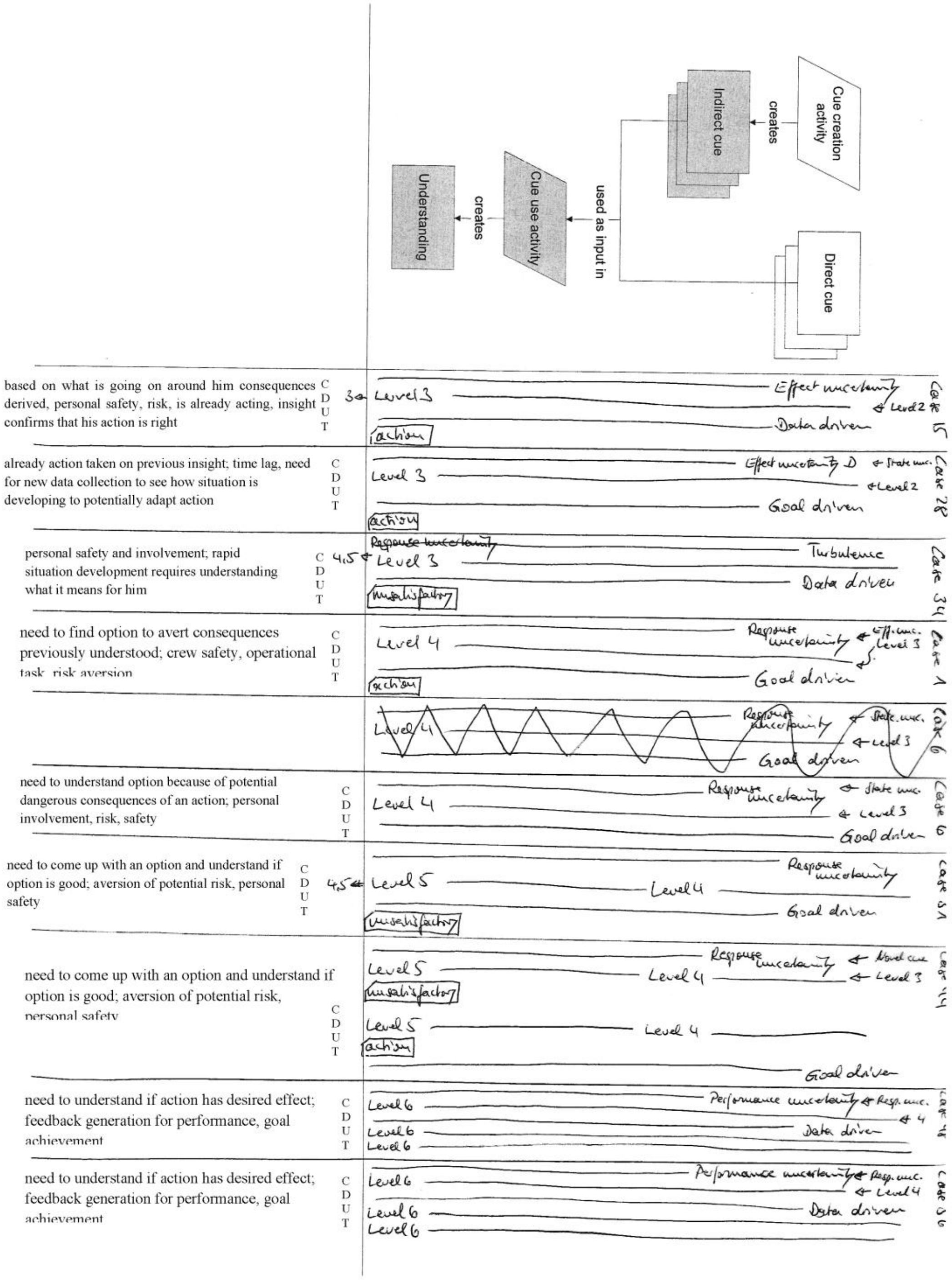
U = Level of understanding T = Cue type

Figure D8b – Analysis of four mechanisms in the simple process (continued)



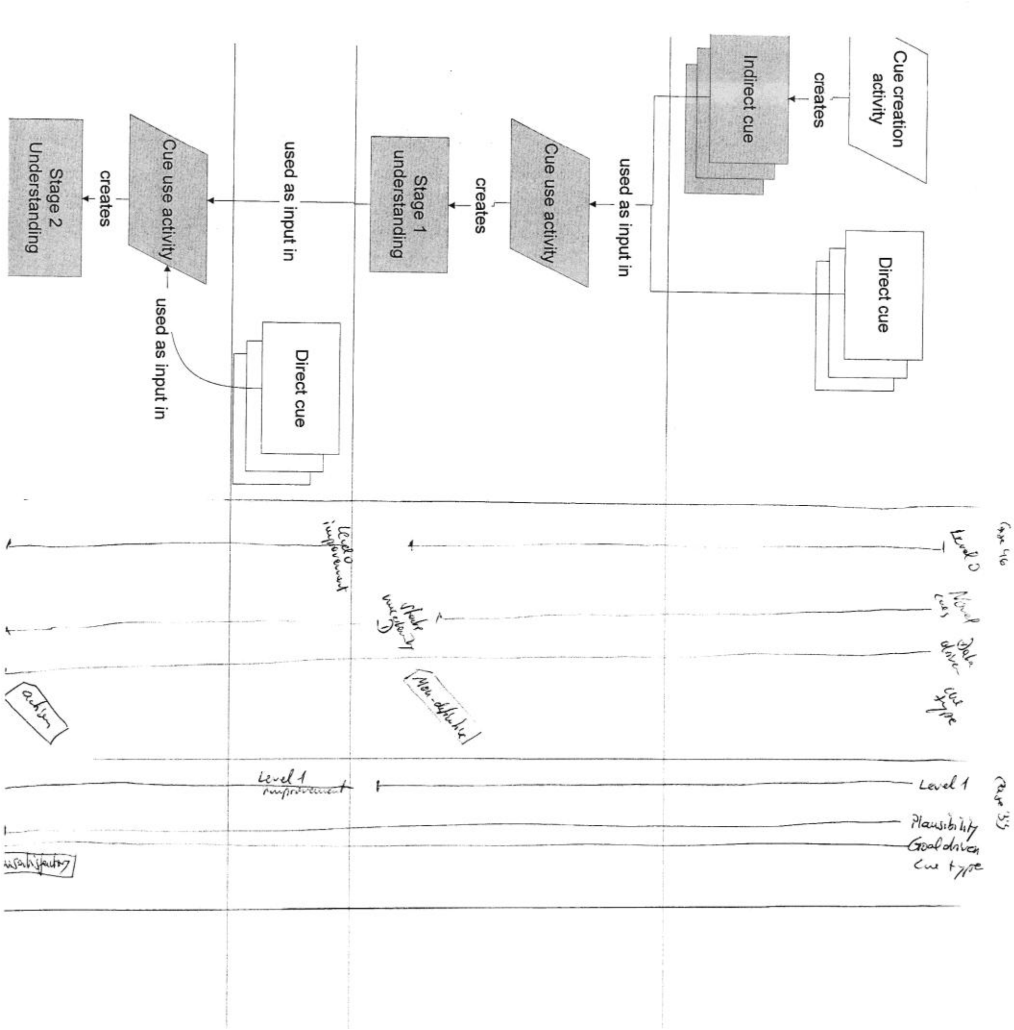
C = Sensemaking context D = Data/goal driven
U = Level of understanding T = Cue type

Figure D8c – Analysis of four mechanisms in the simple process (continued)



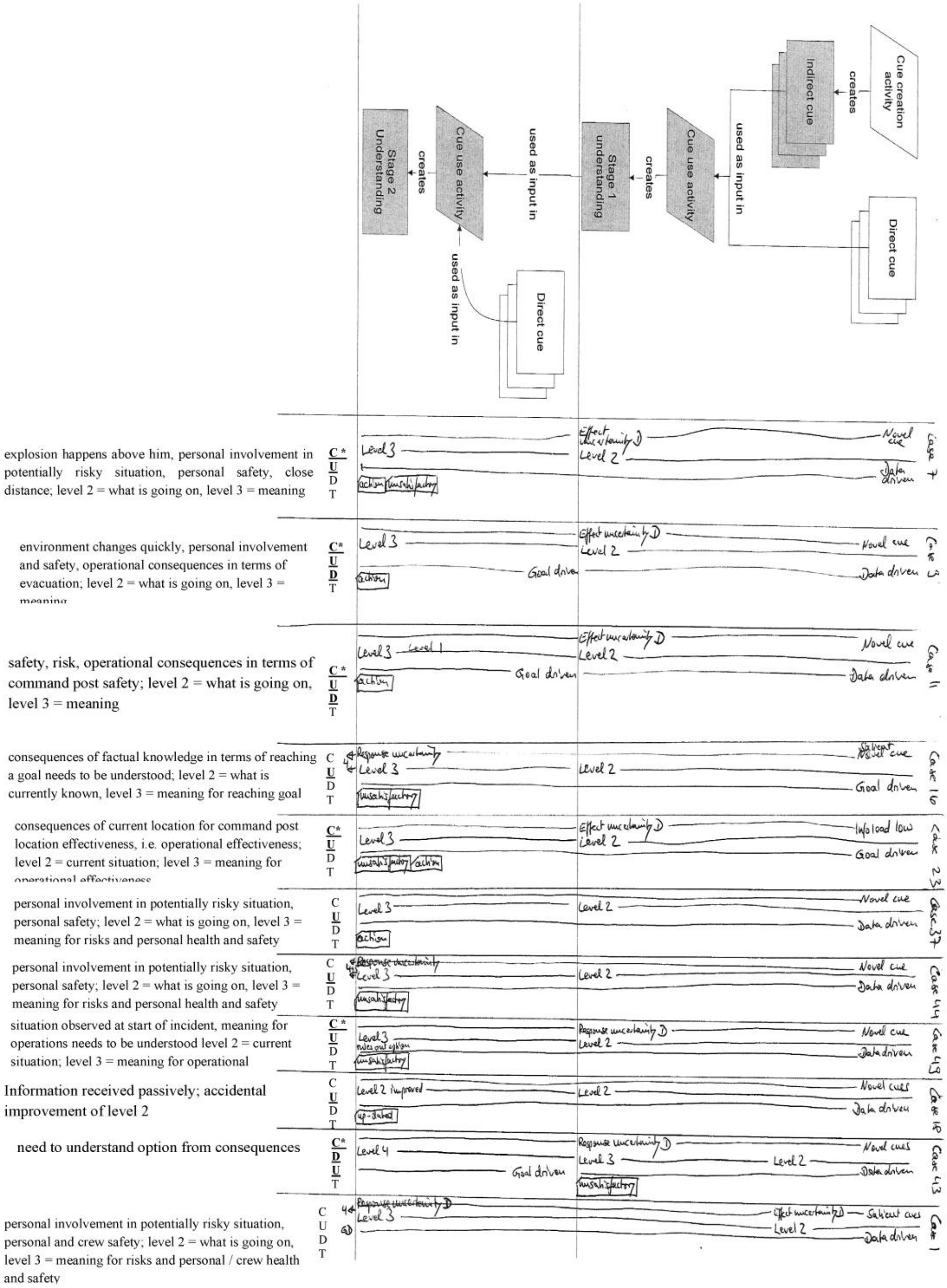
C = Sensemaking context D = Data/goal driven
U = Level of understanding T = Cue type

Figure D8d – Analysis of four mechanisms in the simple process (continued)



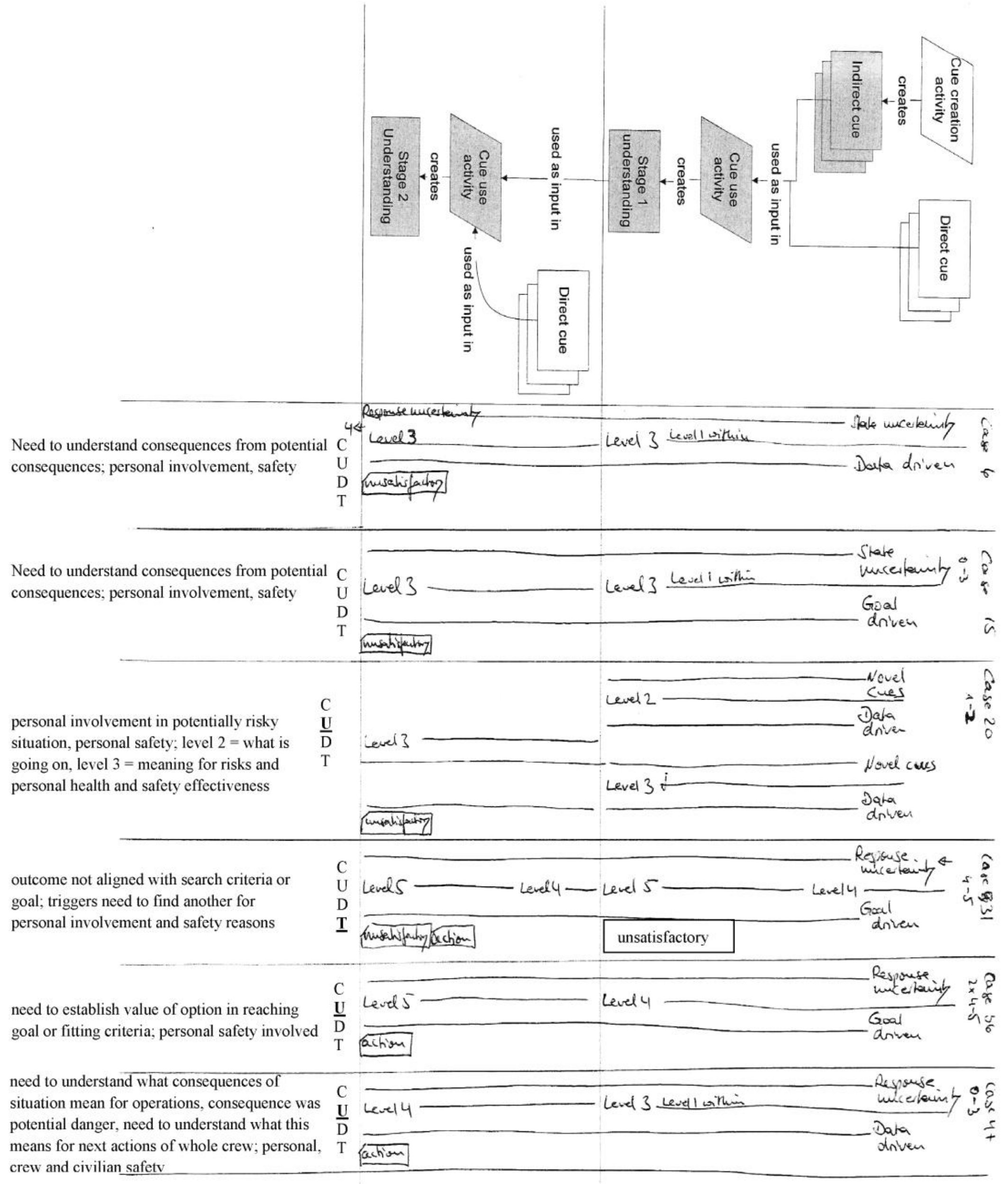
C = Sensemaking context D = Data/goal driven
U = Level of understanding T = Cue type

Figure D8e – Analysis of four mechanisms in the multiple stage process



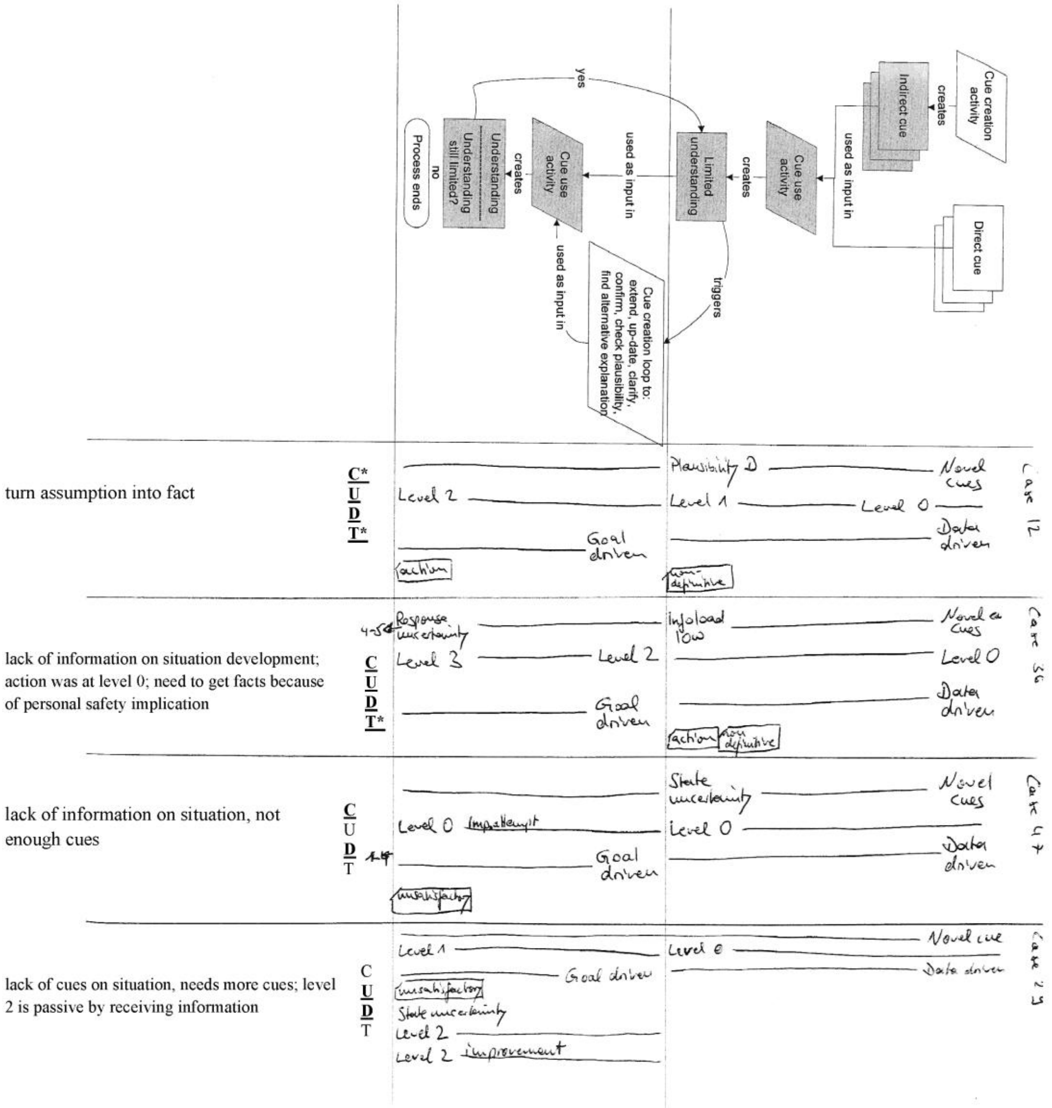
C = Sensemaking context D = Data/goal driven
U = Level of understanding T = Cue type

Figure D8f – Analysis of four mechanisms in the multiple stage process (continued)



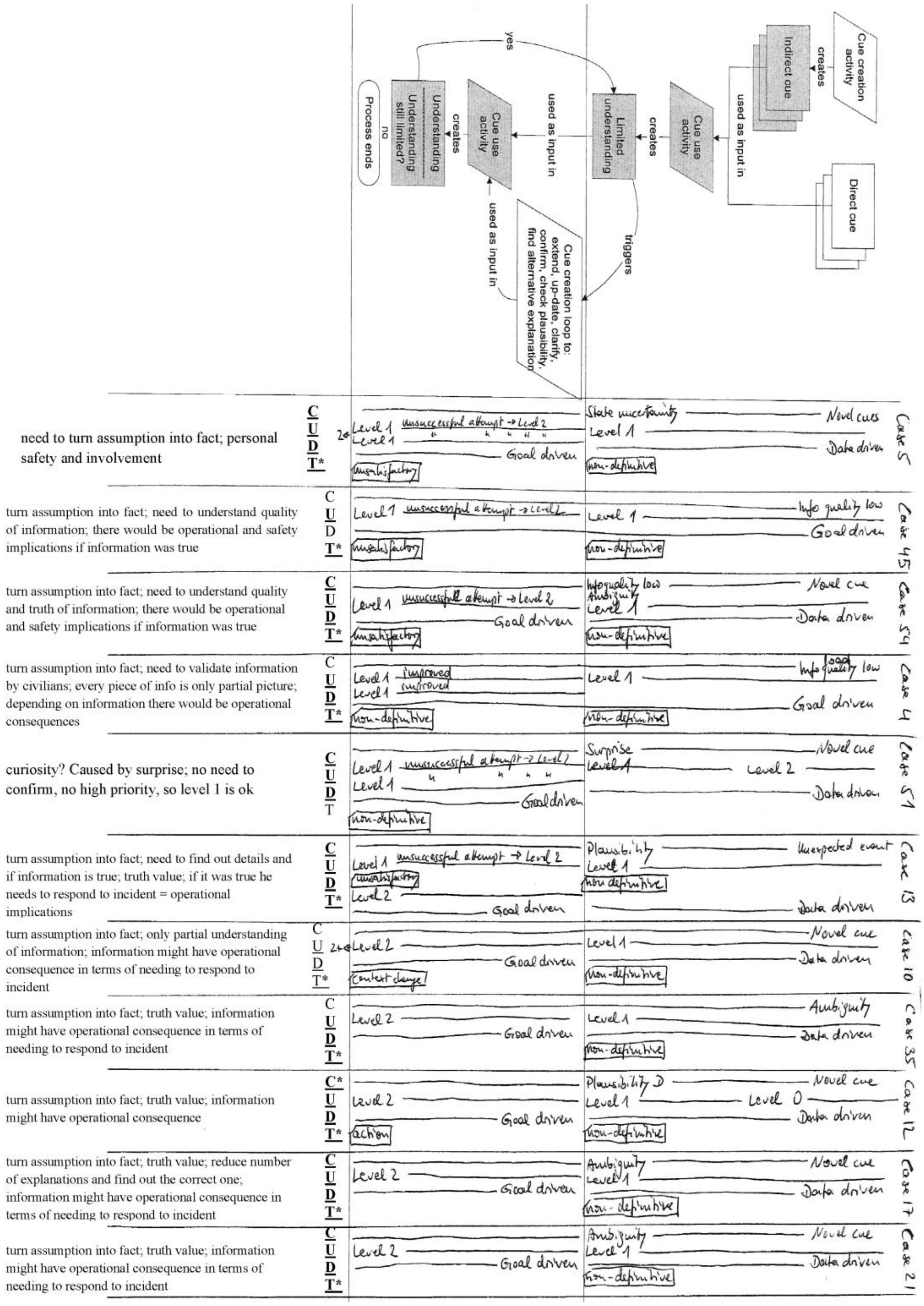
C = Sensemaking context D = Data/goal driven
U = Level of understanding T = Cue type

Figure D8g – Analysis of four mechanisms in the multiple stage process (continued)



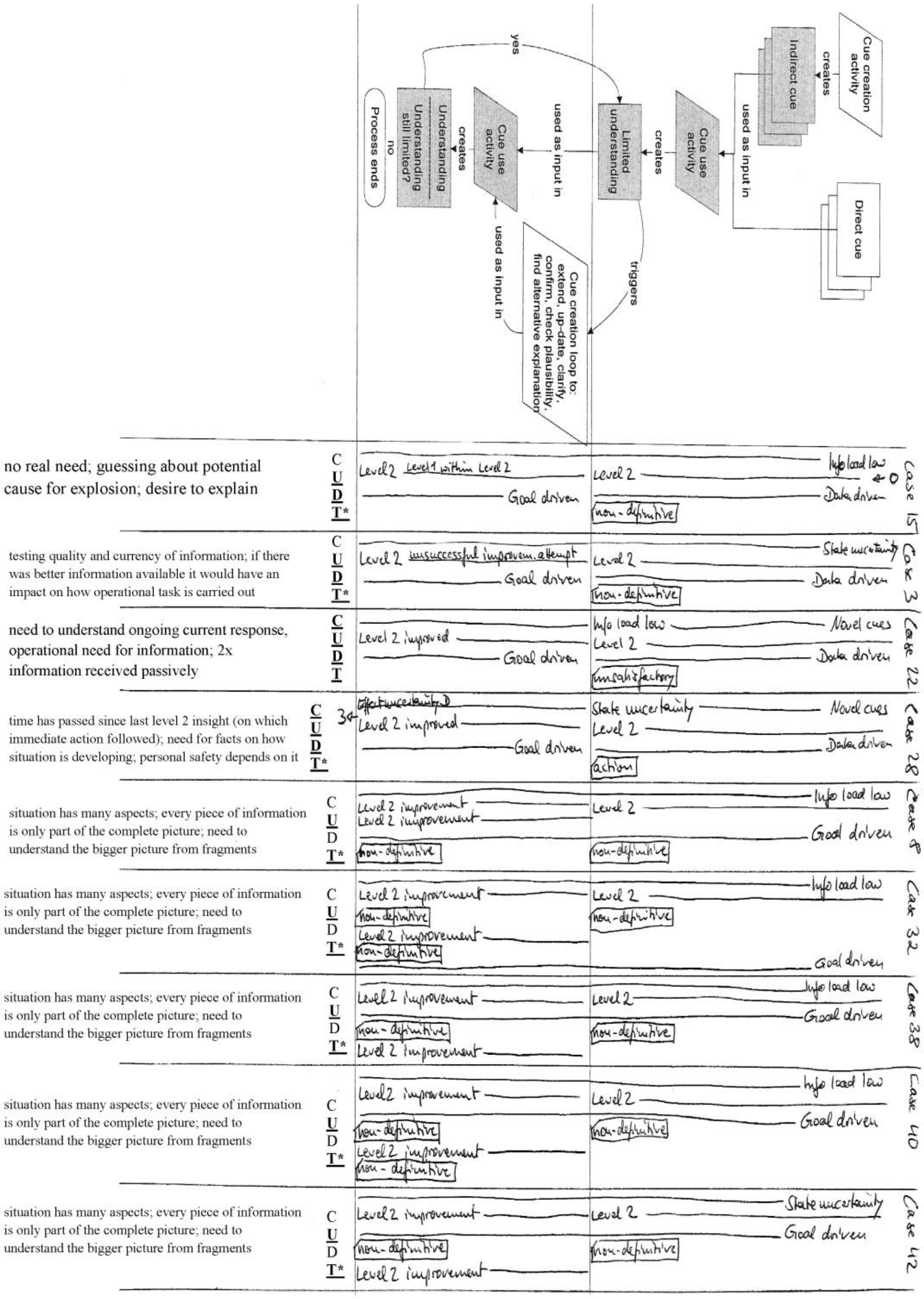
C = Sensemaking context　　D = Data/goal driven
U = Level of understanding　　T = Cue type

Figure D8h – Analysis of four mechanisms in the emergent process



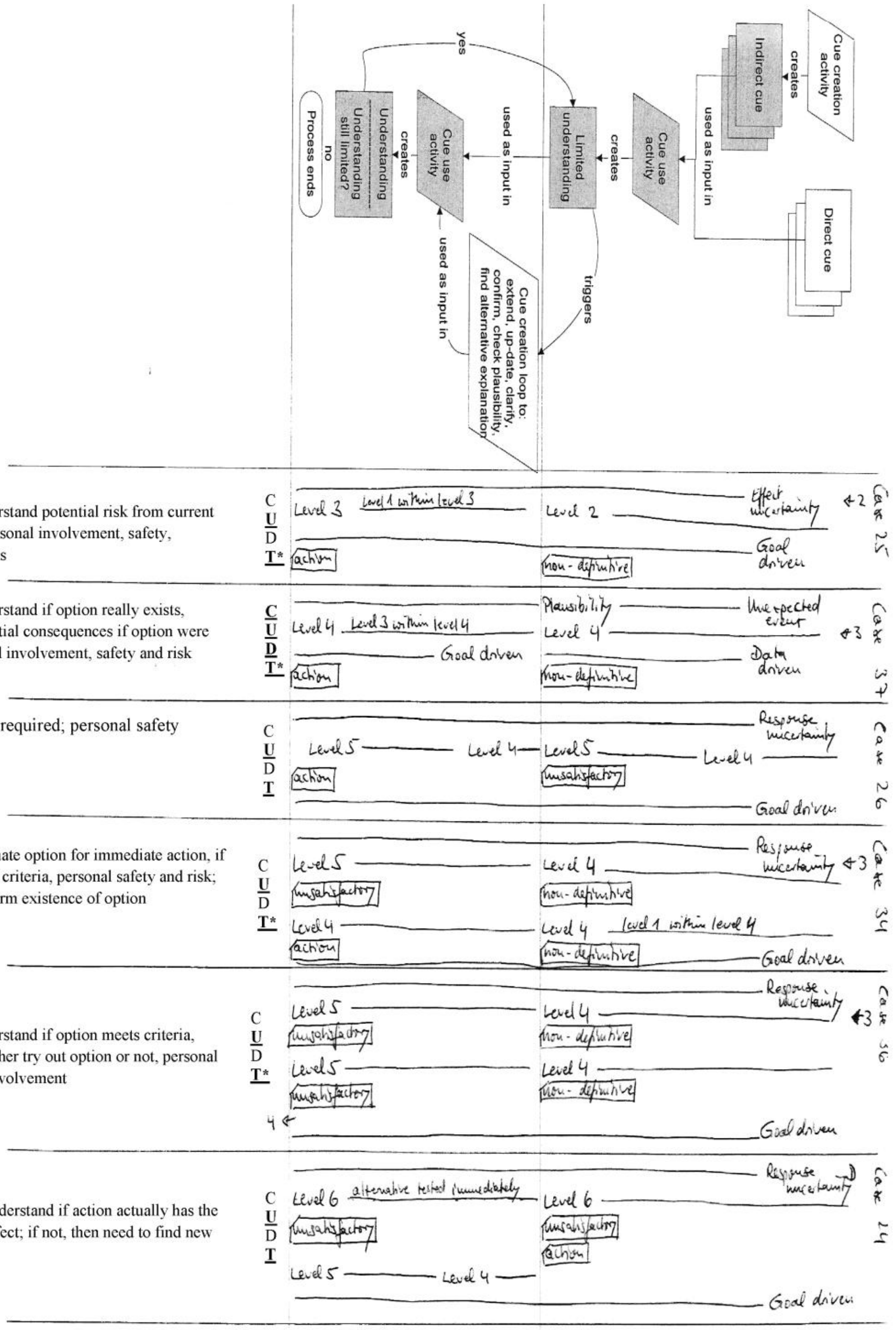
C = Sensemaking context
U = Level of understanding
D = Data/goal driven
T = Cue type

Figure D8i – Analysis of four mechanisms in the emergent process (continued)



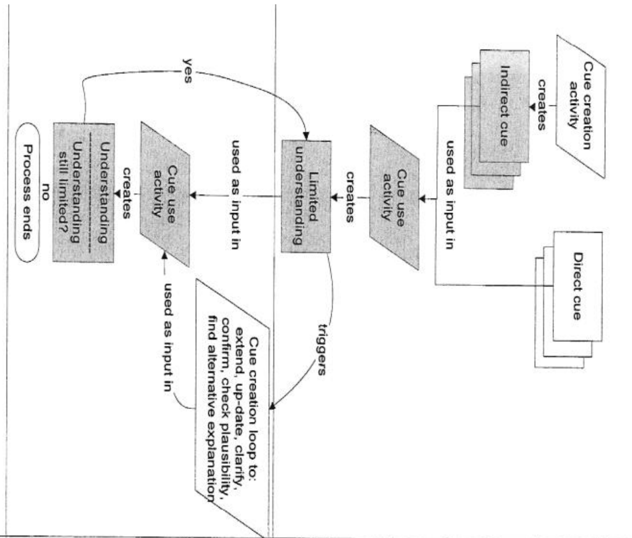
C = Sensemaking context
U = Level of understanding
D = Data/goal driven
T = Cue type

Figure D8j – Analysis of four mechanisms in the emergent process (continued)



C = Sensemaking context D = Data/goal driven
U = Level of understanding T = Cue type

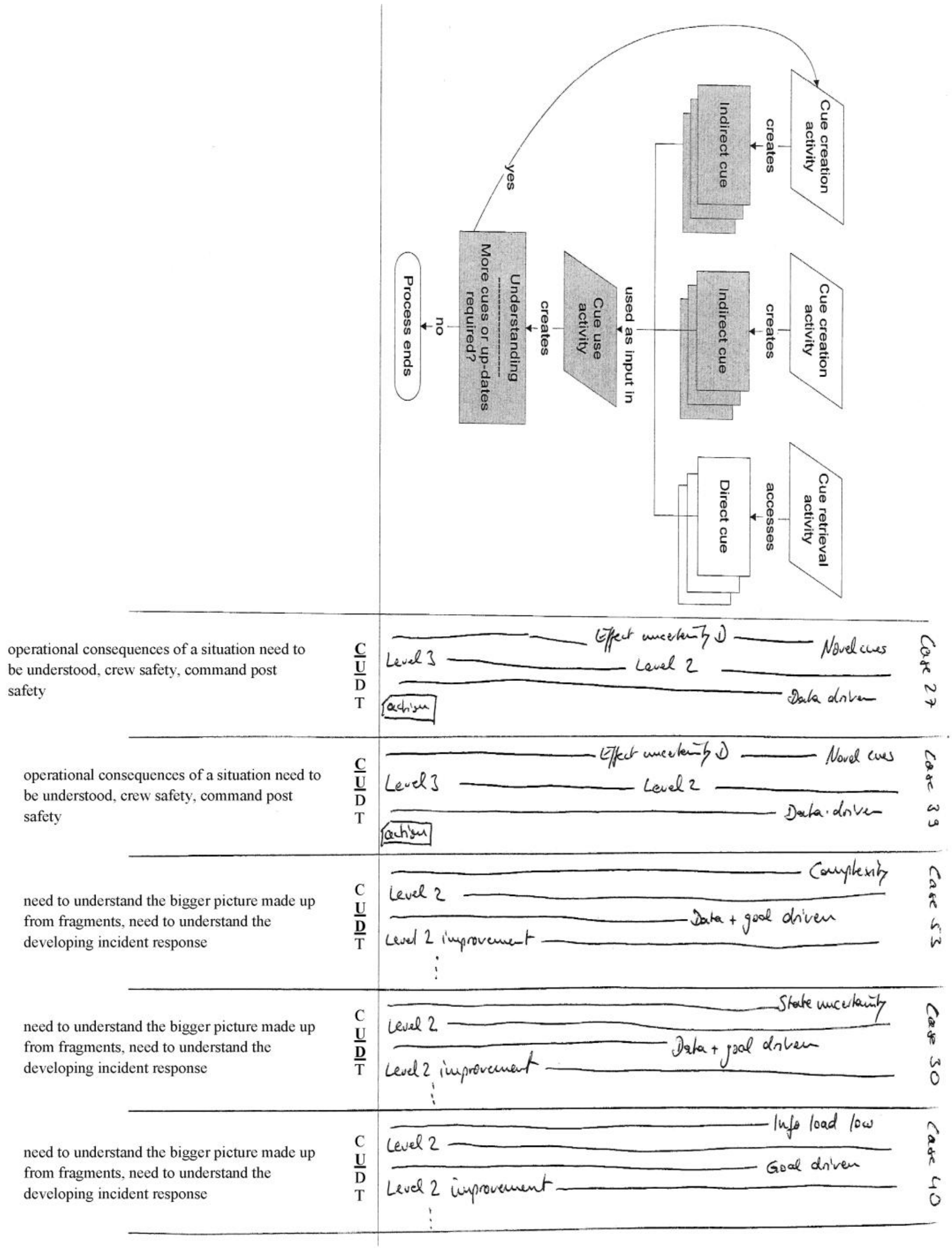
Figure D8k – Analysis of four mechanisms in the emergent process (continued)



lack of information on situation, not enough cues	**C** **U** **D** **T***	Level 0 unsuccessful attempt -> level 2 unsatisfactory Goal driven	State uncertainty — Novel cues Level 0 non-definitive Data driven
Need to explain novel cues, potential crew safety, personal involvement	C **U** **D** **T**	Level 1 Data driven non-definitive	
Need to confirm assumptions	C **U** **D** **T***	Level 2 Goal driven Ambiguity	
Need to explain ambiguous information	**C** **U** **D** **T**	Level 2 level 1 within level 2 Data driven non-definitive	
Need to confirm potential explanation	C **U** **D** **T***	Level 2 confirmation Response uncertainty Goal driven	
Need to collect orders for response to events	**C** **U** D T	Level 2 unsuccessful attempt -> Level 4 Ambiguity Goal driven unsatisfactory	
Need to find out consequences from facts	**C** **U** **D** **T**	Level 3 Level 1 within level 3 non-definitive Data driven ⇓ another model ⇓ level 1 + 4	

C = Sensemaking context D = Data/goal driven
U = Level of understanding T = Cue type

Figure D8l – Analysis of four mechanisms in the emergent process (continued)



C = Sensemaking context
U = Level of understanding
D = Data/goal driven
T = Cue type

Figure D8m – Analysis of four mechanisms in the multiple input process

Appendix D9 - Levels of understanding and underlying mechanisms in the simple process

Episodes by level

Simple process level 0

- Cue perception triggers cue use (episode 15)
- Understanding triggers context change (information load low) and a new process – episode 15 → **perception of new cues triggers need to understand them**

Simple process level 1

- Level 1 as outcome; new simple process triggered because new cues become available which take understanding to level 2 (episode 2)
- Observation of cues leads to assumption of what is going on (level 1); now context change: novel cues 3x, i.e. very rapid situation development; new cues are used each time to up-date understanding of what is going on, moving from level 1 to 3; (episode 20) → **the underlying mechanism here is the situation development that constantly provides new cues for which meaning has to be created**

Simple process level 2

- Unresolved episode, he observes facts but cannot explain them (stays on level 2) (episode 14)
- Level 2 achieved, seems satisfied with explanation, just observes situation development; later new cues become available (emergent process triggered) (episode 19)
- 3x simple model, each time the situation throws up new cues, a new development, first one for level 1, second and third one are just compared to analogy – level 2; then again novel cues and he moves to level 3 (episode 20)
- emergent process resulted in level 2 previously; now novel cues become available which are just used to up-date level 2 (episode 21)
- Results in level 2; triggers new gap, new process to move to level 3 and context change: effect uncertainty (episode 25); later new information is used in another simple process, which confirms earlier level 3 understanding
- Previous multiple stage processes resulted in level 1; insights from each of the two processes are now combined with new information in a simple process resulting in level 2 (episode 33) → **does not have its own sensemaking context as trigger; is just continuation of previous models; only identifiable by level!**
- Wants to know specific piece of information, simple process results in level 2, no need to move further (episode 41)
- Just fact recording in 2 simple processes, finding an explanation for cues, becomes relevant in later processes to find options (episode 44)
- He is in a danger zone and checks if there is anything dangerous in the cloud; triggers cue creation, i.e. observation of facts (level 2), for which meaning is created in form of consequences at the cue use stage (level 3); (episode 50) – started by effect uncertainty, no context change

- New cues become available that are already familiar, he uses them to conclude that something specific is happening (tower collapse) (episode 57) – no context change
- Results in level 2, an expectation (he is sure this will happen and treats it as a fact), this expectation is later violated (context change: novel cues), drop to level 1, and triggers a new emergent process, which is unsuccessful in regaining level 2 (episode 54)

Simple process level 3

- New situation development provides cues that are used to create meaning in terms of consequences (level 3) (episode 15) → suddenly starts thinking about something new, i.e. new process starts.
- Emergent process resulted in level 2 and up-date of level 2, this triggers context change descriptor: effect uncertainty; simple process used to speculate that something not good is in the cloud that is going to overtake him with the consequence of needing shelter (level 3) (episode 28) → **personal safety**
- Consequences for himself from current situation derived, results in urgent need for action and context change: response uncertainty; moves then to level 4 and 5 (episode 34) → **personal health risk needs to be acted upon**

Simple process level 4

- Preceded by multiple stage process (level 2 and 3), resulting in consequences of being in hazard zone, triggers context change: response uncertainty, creates need for shelter which should guide search for option; followed by simple process searching for cover and finding it (level 4), action follows (episode 1) → **immediate need for option required, crew safety**
- Preceded by multiple stage process (level 3) where potential consequence of leaving lobby is dangerous; triggers context change: response uncertainty; starts thinking about alternative when he is interrupted, i.e. process not finished (episode 6) → **need for option from level 3 where essentially an option turned out to be too dangerous, i.e. new one needed**
- First part is option generation brought about by observation activity (level 4), second part, i.e. cue use, about evaluation of that option (level 5), outcome is unsatisfactory, thus no progress to implementing option, drop back to level 4 (continues as multiple stage process because of time lag between the 2 processes) (episode 31) → **there must be a goal in advance that guides option search; he has just been through experience of collapsing tower and needs shelter**
- Previously level 2 and 3, resulting in immediate need for action but it is not clear what action should be taken, triggers response uncertainty; triggers simple process where first part is finding option by observation of surrounding (level 4) and second part (cue use) about comparing it to stability criteria (level 5) with negative outcome, i.e. drop back to level 4; triggers another simple process where option is retrieved from memory (level 4) and evaluated (level 5) with positive outcome leading to action (episode 44) → **if it is not clear what action could be taken or if a goal exists but no option, then process triggered to find option**

Simple process level 5

- First part is option generation brought about by observation activity (level 4), second part, i.e. cue use, about evaluation of that option (level 5), outcome is unsatisfactory, thus no progress to implementing option, drop back to level 4 (continues as multiple stage process because of time lag between the 2 processes) (episode 31) → **evaluation is needed to understand if option can be carried out**
- Previously level 2 and 3, resulting in immediate need for action but it is not clear what action should be taken, triggers response uncertainty; triggers simple process where first part is finding option by observation of surrounding (level 4) and second part (cue use) about comparing it to stability criteria (level 5) with negative outcome, i.e. drop back to level 4; triggers another simple process where option is retrieved from memory (level 4) and evaluated (level 5) with positive outcome leading to action (episode 44) → **evaluation is needed to understand if option fulfils criteria**

Simple process level 6

- Preceded by option generation (level 4), level 5 not described but seems to be no evaluation of a single option but comparison of 2 possibilities against each other; although disadvantage of chosen option is anticipated (way out may be blocked by debris) he goes for it; simple processes follow to check his own progress because he cannot see where he is going and if he already reached the outside (level 6) (episode 48) → **performance check triggered because he needs to understand if reached his goal and if corrective action is required**
- Preceded by level 1, 3 and 4; simple processes follow to check his own progress because he cannot see where he is going and if he already reached the outside (level 6) (episode 56) → **performance check triggered because he needs to understand if reached his goal and if corrective action is required**

Other mechanisms

- Episode 15: level 0; immediate action, then time lag until new process started because of need for more information on current development, needed for personal involvement and safety implications
- Episode 2: level 1; insight is enough for action, no means to confirm anyway
- Episode 20: level 2; rapid succession of novel cues (tower collapse), fact recording, later because of novel cues to level 3 in new process
- Episode 14: level 2; just observes facts but cannot make sense of them
- Episode 19: level 2; new cues need explanation; time lag until new process started
- Episode 33: level 2; is there to integrate 2 previous insights from different processes with new information; integration purpose, pulling fragments together
- Episode 41: level 2; serves information need, simple request for information
- Episode 44: level 2; just novel cues explained; noticing new facts and explaining them, no need to progress to further levels; but comes in useful later
- Episode 57: level 2; novel cues need explanation; safety because the same cue were experienced before and had a bad meaning attached, i.e. plane crash; immediate action, no need to progress further because implications are already known

- Episode 54: level 2; operational task, potential safety implications for operations; time lag before new process starts that re-uses insight
- Episode 21: level 2+; sensemaking challenge was resolved in process before; however, after some time new information becomes available that enhances previous understanding; i.e. new cues integrated with previous understanding
- Episode 25: level 2; expectation formed; time lag until situation changes later and new process is started
- Episode 50: level 2-3; just facts recorded and meaning immediately established; no need to continue because of satisfactory outcome
- Episode 15: level 3; based on what is going on around him consequences derived, personal safety, risk, is already acting, insight confirms that his action is right
- Episode 28: level 3; already action taken on previous insight; time lag, need for new data collection to see how situation is developing to potentially adapt action
- Episode 34: level 3; personal safety and involvement; rapid situation development requires understanding what it means for him
- Episode 1: level 4; need to find option to avert consequences previously understood; crew safety, operational task, risk aversion
- Episode 6: level 4; need to understand option because of potential dangerous consequences of an action; personal involvement, risk, safety
- Episode 31: level 4-5; need to come up with an option and understand if option is good; aversion of potential risk, personal safety
- Episode 44: level 4-5; need to come up with an option and understand if option is good; aversion of potential risk, personal safety
- Episode 48: level 6; need to understand if action has desired effect; feedback generation for performance, goal achievement
- Episode 56: level 6; need to understand if action has desired effect; feedback generation for performance, goal achievement

Appendix D10 - Levels of understanding and underlying mechanisms in the emergent process

Episodes by level

Emergent process at level 0

- Cue perception triggers cue use (first part of first stage in emergent process - episode 12, 29) → **perception of new cues triggers need to understand them**
- First part of emergent model results in limited understanding (level 0), then context change to information load low and data collection loop triggered (episode 36) → **perception of new cues triggers need to collect more data on the situation that is going on before an explanation is attempted; perception of new cues focuses attention on situation; however, level 0 already triggers action to run away**
- Episode 47 – first part of emergent model results in limited understanding (level 0), which triggers unsuccessful a data collection loop (still at level 0), which triggers an explanation loop (move to level 1) → **perception of new cues triggers need to collect more data on the situation that is going on to create explanation; attempt to move to level 2 not successful as no new information available, thus, level 1 first**

Emergent process at level 1

- First part of emergent model results in limited understanding (level 1), triggers 2 unsuccessful data collection loops to move to level 2 (episode 4) – context change
- First part of emergent model results in limited understanding (level 1), triggers unsuccessful data collection loop to move to level 2 (episode 5) – context change
- First part of emergent model results in limited understanding (level 1), triggers data collection loop to move to level 2 (episode 10, 35, 47) – no context change
- First part of emergent model results in limited understanding (level 1), triggers confirmation loop to move to level 2 (episode 12) – context change descriptor
- First part of emergent model results in limited understanding (level 1), triggers unsuccessful confirmation loop (stays at level 1), triggers successful confirmation loop to move to level 2 (episode 13) – context change
- First part of emergent model results in limited understanding (level 1), triggers confirmation loop to move to level 2 (episode 17, 21) – context change
- Emergent model results in level 1 understanding, triggers multiple data collection loops to move to level 2 (episode 29) – context change
- Level 1 triggers emergent process to move to level 2 (episode 42) – no context change
- First part of emergent model results in limited understanding (level 1), triggers unsuccessful data collection loop to move to level 2 (episode 45) – no context change

- First part of emergent process results in level 2, an expectation (he is sure this will happen and treats it as a fact), this expectation is violated (context change: surprise), drop to level 1, and triggers multiple explanation loops about possibilities why this is happening but cannot be confirmed, i.e. unsuccessful attempt to get back to level 2 (episode 51) → **he does not continue to try and confirm his level 1 assumptions because the event has no direct operational consequence, in fact, a problem which he expected to hinder operations is not there; thus, no need to follow this up**

- Results in level 2, an expectation (he is sure this will happen and treats it as a fact), this expectation is later violated (context change: novel cues), drop to level 1, and triggers a new emergent process; first part of emergent process is about integrating new information with earlier expectancy resulting in contradiction, which is limited insight and requires confirmation; triggers data collection loop for the purpose of confirmation, which is unsuccessful, i.e. no regaining of level 2 (episode 54) → **operational need to understand significance of information triggers loop**

Emergent process at level 2

- First part of emergent process results in level 2 but is limited because not known if there is better information, triggers unsuccessful confirmation loop to improve level 2 (episode 3) – no context change
- Two unsuccessful data collection loops in second part of emergent process, triggered by limited understanding (level 1) – context change; move to level 2 comes through outside information (episode 5)
- First part of emergent process results in level 2 but is limited because not the full situation picture, triggers multiple data collection loops to improve level 2 (episode 8) – no context change
- First part of emergent process results in level 1, triggers data collection loop to move to level 2 (episode 10) – no context change
- First part of emergent process results in level 1, triggers confirmation loop to move to level 2 (episode 12) – context change descriptor: plausibility
- First part of emergent process results in level 1, triggers 1 unsuccessful, then successful confirmation loop to move to level 2 (episode 13) – context change descriptor: plausibility
- First part of emergent process results in level 2, triggers 2 explanation loops resulting in speculation about causes, i.e. level 1 in level 2; later moves on to level 3 (episode 15) – no context change
- First part of emergent process results in level 1, triggers confirmation loop to move to level 2 (episode 17) – context change: ambiguity
- Is continuation from simple process; First part of emergent process results in correction of level 2 from original simple process; triggers projection loop to foresee consequences, i.e. move to level 3 (episode 19) – context change descriptor: effect uncertainty
- First part of emergent process results in level 1, triggers confirmation loop to move to level 2 (episode 21) – context change: plausibility
- First part of emergent process results in level 2, triggers a new question in his mind which leads to confirmation loop to improve level 2 (episode 22) – context change: info load low

- First part of emergent process results in level 2 as well as action to run away which means that he does not know how the situation develops further because he cannot look at it for the moment, then triggers a data collection loop to up-date level 2 (episode 28) – context change: state uncertainty; this triggers new process to think about consequences of what he sees now
- Emergent process results in level 1 understanding; then multiple data collection loops to move to level 2 and improve it (episode 30) – context change to state uncertainty
- First part of emergent process results in level 2 but is limited because not the full situation picture, triggers multiple data collection loops to improve level 2 (episode 32 – same as episode 8) – no context change
- First part of emergent process results in level 1, triggers confirmation loop to move to level 2 (episode 35) – no context change
- First part of emergent process results in level 0 and action to run away, then after some time triggers data collection loop, where the new cues are observed facts (level 2) and their use results in level 3 (episode 36) – context change before loop to information load low
- First part of emergent process results in level 2 but is limited because not the full situation picture, triggers multiple data collection loops to improve level 2 (episode 38 – same as episode 8 and 32) – no context change
- First part of emergent process results in level 2 but is limited because not the full situation picture, triggers multiple data collection loops to improve level 2 (episode 40 – same as episode 8, 32, 38) might be seen as multiple input generation – no context change
- First part of emergent process results in level 2 but is limited because not the full situation picture, triggers multiple data collection loops to improve level 2 (episode 42 – same as episode 8, 32, 38, 40) – no context change
- One very long emergent process with multiple loops; previous loop resulted in level 1, triggers data collection loop resulting in gathered facts (level 2) but limited understanding because context change: ambiguity, i.e. meaning of facts not understood, triggers explanation loop resulting in possible explanations, triggers data collection loop to confirm explanation resulting in clarification (level 2) and reducing ambiguity but triggering response uncertainty – continues to higher levels in the following (episode 47)
- First part of emergent process results in level 2, an expectation (he is sure this will happen and treats it as a fact), this expectation is violated (context change: surprise), drop to level 1, and triggers multiple explanation loops about possibilities why this is happening but cannot be confirmed, i.e. unsuccessful attempt to get back to level 2 (episode 51)

Emergent process at level 3

- Is continuation from simple process; First part of emergent process results in correction of level 2 from original simple process; triggers projection loop to foresee consequences, i.e. move to level 3 (episode 19) – context change descriptor: effect uncertainty

- Earlier simple process results in level 2 expectation that he is overcome by cloud; triggers new gap, new emergent process to move to level 3 and context change: effect uncertainty (episode 25); first part of emergent process is about observing cloud content, this is limited insight as he cannot be sure what is in the cloud; triggering projection loop what else might be in the cloud that might hit him (level 3 consequences of being in a cloud); later new information is used in another simple process, which confirms earlier level 3 understanding →
- First part of emergent process results in level 0 and action to run away, then after some time triggers data collection loop, where the new cues are observed facts (level 2), second part of the loop (the cue use) results in level 3, which is the consequences of a situation development; insight results in context change: response uncertainty, i.e. moves on to level 4 and 5 (episode 36) – context change before loop to information load low → **this one is a bit like the simple process for level 3 where meaning in terms of consequences has to be created for newly observed cues**
- Emergent process with multiple loops; at some point he tries to get answers from command post but they don't answer; triggers context change: ambiguity and explanation loop to come up with potential reasons why they don't answer (level 3), i.e. potential consequences of the tower collapse (episode 47) → **he leaves it at this explanation and does not continue, there is nothing to do about**

Emergent process at level 4

- Emergent process with multiple loops, first stage results in unsuccessful trial, as does the testing loop for an alternative (level 6 – performance unsatisfactory), drop from level 6 to level 4; triggers new loop to hypothesise about another possible option (level 4), evaluation (level 5) not described because it is not a sensemaking problem, i.e. he knows that the option is right, he just does not know if it actually works, which would be level 6 (episode 24) – episode is interrupted
- Starts with a goal (getting close to tower), which triggers visualisation/projection loop where the first part is the option (level 4) and the use activity about comparing it with the goal (level 5), outcome is unsatisfactory first time; triggers another visualisation/projection loop where the first part is the option (level 4) and the use activity about comparing it with the goal (level 5), this time satisfactory (episode 26) → **trigger is operational need to get to the scene quick, trigger for second loop is unsatisfactory evaluation outcome**
- Episode started with level 3 (need to get out of the place he is) and triggered context change to response uncertainty; first part of emergent process is about generating option (level 4), this is limited insight because it is not yet understood if option has any value, this triggers projection/visualisation loop to test option in his mind (level 5) with negative outcome, causes drop back to level 4; makes assumption about existence of another option (level 4), triggers a confirmation loop confirmation loop to check existence, positive outcome (still on level 4); direct action without evaluation (episode 34) → **negative evaluation outcome results in need for option generation**
- Episode started with progress from level 0 to 3, the need for immediate action and finding shelter; triggers 2x emergent process where first stage is option generation by observing terrain (level 4) and the following loop (testing and

projection) is evaluation (level 5); outcome is negative each time, triggers another option generation (see multiple stage process) (episode 36) → **negative evaluation outcome results in need for option generation, limited insight is in not understanding if option is a good one; in this example context change would not be able to explain the 2 stages in the process!**

- Previous level 3; now unexpected event triggers first stage of emergent process, resulting in assumption about existence of an option; triggers a confirmation loop testing if the option exists by checking consequences that should occur if option was real (level 3 within level 4), resulting in confirmation of option existence (level 4) and adaptation of behaviour to changed situation (episode 37) – context change: plausibility → **limited insight consists in not understanding if option is real**

Emergent process at level 5

- Emergent process with multiple loops, first stage results in unsuccessful trial, as does the testing loop for an alternative (level 6 – performance unsatisfactory), drop from level 6 to level 4; triggers new loop to hypothesise about another possible option (level 4), evaluation (level 5) not described because it is not a sensemaking problem, i.e. he knows that the option is right, he just does not know if it actually works, which would be level 6 (episode 24) – episode is interrupted
- Starts with a goal (getting close to tower), which triggers visualisation/projection loop where the first part is the option (level 4) and the use activity about comparing it with the goal (level 5), outcome is unsatisfactory first time; triggers another visualisation/projection loop where the first part is the option (level 4) and the use activity about comparing it with the goal (level 5), this time satisfactory (episode 26) → **trigger is operational need to get to the scene quick, trigger for second loop is unsatisfactory evaluation outcome; evaluation is triggered because he needs to understand if the option is in line with his goal**
- Episode started with level 3 (need to get out of the place he is) and triggered context change to response uncertainty; first part of emergent process is about generating option (level 4), this is limited insight because it is not yet understood if option has any value, this triggers projection/visualisation loop to test option in his mind (level 5) with negative outcome, causes drop back to level 4; makes assumption about existence of another option (level 4), triggers a confirmation loop confirmation loop to check existence, positive outcome (still on level 4); direct action without evaluation (episode 34) → **evaluation triggered to see if it fits with his criteria of getting out quick, personal safety matter**
- Episode started with progress from level 0 to 3, the need for immediate action and finding shelter; triggers 2x emergent process where first stage is option generation by observing terrain (level 4) and the following loop (testing and projection) is evaluation (level 5); outcome is negative each time, triggers another option generation (see multiple stage process) (episode 36) → **triggers physical testing to see if it is aligned with goal; triggers mental projection to understand potential consequences of that option**

Emergent process at level 6

- Emergent process with multiple loops, first stage results in unsuccessful trial, as does the testing loop for an alternative (level 6 – performance unsatisfactory), drop from level 6 to level 4; triggers new loop to hypothesise about another possible option (level 4), evaluation (level 5) not described because it is not a sensemaking problem, i.e. he knows that the option is right, he just does not know if it actually works, which would be level 6 (episode 24) – episode is interrupted **→ if desired performance is not achieved, then a new option search is triggered, i.e. new process part**

Other mechanisms

- Episode 36: level 0-3: lack of information on situation development; action was at level 0; need to get facts because of personal safety implication
- Episode 47: level 0-0+; lack of information on situation, not enough cues
- Episode 29: level 0-1, 2, 2+; lack of cues on situation, needs more cues; level 2 is passive by receiving information
- Episode 25: level 2-3 (level 1 within); need to understand potential risk from current situation, personal involvement, safety, potential risks
- Episode 37: level 4-4 (level 3 within); need to understand if option really exists, testing potential consequences if option were real, personal involvement, safety and risk
- Episode 24: level 6-6, 4-5; need to understand if action actually has the desired effect; if not, then need to find new option

What is the need to move from level 1 to 2?

- Episode 12: turn assumption into fact
- Episode 5: level 1-1, 1 (unsuccessful moves); need to turn assumption into fact; personal safety and involvement
- Episode 45: level 1-1 (unsuccessful move); turn assumption into fact; need to understand quality of information; there would be operational and safety implications if information was true
- Episode 54: level 1-1 (unsuccessful move); turn assumption into fact; need to understand quality and truth of information; there would be operational and safety implications if information was true
- Episode 4: level 1-1+, 1+; turn assumption into fact; need to validate information by civilians; every piece of info is only partial picture; depending on information there would be operational consequences
- Episode 51: level 2, 1 – 1, 1 (unsuccessful move): curiosity? Caused by surprise; no need to confirm, no high priority, so level 1 is ok
- Episode 13: level 1-1, 2; turn assumption into fact; need to find out details and if information is true; truth value; if it was true he needs to respond to incident = operational implications
- Episode 10: level 1-2; turn assumption into fact; only partial understanding of information; information might have operational consequence in terms of needing to respond to incident
- Episode 35: level 1-2; turn assumption into fact; truth value; information might have operational consequence in terms of needing to respond to incident

- Episode 17: level 1-2; turn assumption into fact; truth value; reduce number of explanations and find out the correct one; information might have operational consequence in terms of needing to respond to incident
- Episode 21: level 1-2; turn assumption into fact; truth value; information might have operational consequence in terms of needing to respond to incident

What is the need to move from level 2 to an improved level 2?

- Episode 15: level 2-2(1 within); no real need; guessing about potential cause for explosion; desire to explain
- Episode 3: 2-2 (unsuccessful move): testing quality and currency of information; if there was better information available it would have an impact on how operational task is carried out
- Episode 22: level 2-2+, 2+, 2+; need to understand ongoing current response, operational need for information; 2x information received passively
- Episode 28: level 2-2+; time has passed since last level 2 insight (on which immediate action followed); need for facts on how situation is developing; personal safety depends on it
- Episode 8, 32, 38, 40, 42: level 2-2+, 2+; situation has many aspects; every piece of information is only part of the complete picture; need to understand the bigger picture from fragments

What is the need to move from level 4 to 5?

- Episode 26: level 4,5 – 4,5; new option required; personal safety
- Episode 34: level 4-5, 4 (level 1 within)-5; need to evaluate option for immediate action, if option meets criteria, personal safety and risk; need to confirm existence of option
- Episode 36: level 4-5, 4-5; need to understand if option meets criteria, needed to either try out option or not, personal safety and involvement

Appendix D11 - Levels of understanding and underlying mechanisms in the multiple stage process

Episodes by level

Multiple stage process at level 0

- Episode 46 – Level 0 outcome of first stage in multiple stage process, triggers 2nd stage to improve understanding - context change descriptor: state uncertainty → **once situation is bracketed, one wants to find out more; presumably to find out if one is affected and should pay continued attention or the situation can be ignored; I cannot know if I can ignore what is going on unless I understand what might be or is going on and what consequences might be**

Multiple stage process at level 1

- 2 multiple stage processes result in level 1 understanding, triggers another simple process for integration with other cues and take understanding to level 2 (episode 33) – no context change

Multiple stage process level 2

- First part of first stage is direct understanding of facts (level 2), triggers then cue use activity with additional cue for consequences (level 3) (episode 1) – context change descriptor
- First stage resulting in level 2 understanding – context change descriptor: effect uncertainty; moves on to level 3 (episode 7) → **Need to understand more because a tower collapse is a potential danger**
- First stage resulting in level 2 understanding – context change descriptor: effect uncertainty; moves on to level 3 (episode 9) → **Need to understand safety in the lobby**
- First stage resulting in level 2 understanding – context change descriptor: effect uncertainty; moves on to level 3 (episode 11) → **command post safety**
- First stage resulting in level 2 understanding, moves on to level 3 in second stage (episode 16) – no context change → **pursuit of a goal, i.e. cross lobby**
- First stage resulting in level 2 understanding, level 2 improvement in second stage through direct cues (episode 18) – no context change → **accidental improvement**
- First stage resulting in level 2 understanding, moves on to level 3 in second stage (episode 23) – context change descriptor: effect uncertainty → **optimum command post location, what it means for operation**
- First stage resulting in level 2 understanding, moves on to level 3 in second stage and trained action (episode 37) – no context change → **personal safety at risk here, consequences need to be understood**

- First part of first stage is direct understanding of facts (level 2), triggers then cue use activity for consequences (level 3), second stage is about level 4 (episode 43) – context change descriptor between stages: response uncertainty → **move to level 3 is to create meaning for facts ("ok, I see this is happening but what does it mean?")**
- First stage resulting in level 2 understanding, moves on to level 3 in second stage and trained action (episode 44 – like episode 37) – no context change → **personal safety at risk here, consequences need to be understood**
- First stage resulting in level 2 understanding, moves on to level 3 in second stage (episode 49) – context change descriptor: response uncertainty → **consequences for operational response need to be understood from observed incident**

Multiple stage process at level 3

- First part of first stage resulted in observed facts (level 2), now second part of first stage to come up with possible scenarios (level 3 consequences), second stage about what the consequences of these are (level 3 – consequences from possible scenarios), then moves on to level 4 – context change descriptors between the levels, i.e. effect uncertainty and response uncertainty (episode 1) → **personal safety and crew safety involved**
- First stage is about hypothetical scenarios from facts (level 1 within level 3), second stage is about consequences from the hypothetical scenarios (level 3) (episode 6) → **personal safety and crew safety involved**
- First stage resulting in level 2 understanding – context change descriptor: effect uncertainty; second stage about move to level 3 (episode 7) → **personal safety, he is very close to the tower collapse, question could be here "does this event affect me? Or the operation?"**
- First stage resulting in level 2 understanding – context change descriptor: effect uncertainty; moves on to level 3 in stage 2 (episode 9) → **Affects: personal safety and crew safety as well as operation**
- First stage resulting in level 2 understanding – context change descriptor: effect uncertainty; moves on to level 3 in second stage although these are potential consequences, i.e. level 1 in level 3 (episode 11) → **command post safety**
- First stage is about possible situation development as consequence of what is currently happening (level 1 within level 3), second stage is about consequences from the possible situation development (level 3) (episode 15) → **personal safety involved as he is close to tower collapse; is about potential consequence taken a step further to see what the consequence would be if these consequences become true**
- First stage resulting in level 2 understanding, moves on to level 3 in second stage (episode 16) – no context change → **pursuit of a goal, i.e. cross lobby**
- First stage of process consists of 2 branches, which treat 2 different aspects of the same situation; 1 is about observing what is happening, the other is about projecting the debris spread into the future; i.e. one part of stage 1 is already about potential consequences of what is happening; stage 2 is about integrating both branches to derive consequences of this actual and assumed situation development

(level 3) (episode 20) – no context change → **personal safety as he is standing beneath the tower; both stages are about consequences!!**

- First stage resulting in level 2 understanding, moves on to level 3 in second stage (episode 23) – context change descriptor: effect uncertainty → **optimum command post location, what it means for operation**
- First stage resulting in level 2 understanding, moves on to level 3 in second stage and trained action (episode 37), moves on to level 4 and 5 at later stage and more by accident than deliberately– no context change → **personal safety at risk here, consequences need to be understood**
- First part of first stage is direct understanding of facts (level 2), triggers then cue use activity for consequences (level 3), second stage is about level 4 (episode 43) – context change descriptor between stages: response uncertainty → **move to level 3 is to create meaning for facts ("ok, I see this is happening but what does it mean?"), consequences for operations and operational response is affected here**
- First stage resulting in level 2 understanding, moves on to level 3 in second stage (episode 44 – like episode 37) – no context change → **personal safety at risk here, consequences of situation development need to be understood**
- First stage resulting in level 2 understanding, moves on to level 3 in second stage (episode 49) – context change descriptor: response uncertainty → **consequences for operational response need to be understood from observed incident**

Multiple stage process at level 4

- Special version with loop after second stage; First stage resulting in level 2 understanding, moves on to level 3 in second stage where action is not aligned with goal; triggers the data collection loop to find new cues (episode 16) – no description if successful; context change after level 3 to response uncertainty → **pursuit of a goal, i.e. cross lobby, level 3 results in misalignment, which triggers need for another option**
- Previously level 4 and 5 with drop back; First part of stage 1 is option generation brought about by observation activity (level 4), second part of stage 1, i.e. cue use, about evaluation of that option (level 5), outcome is unsatisfactory, thus no progress to implementing option, drop back to level 4; new option (level 4) needs not be created because he is doing it anyway (crawling away) but is evaluated in second stage with positive outcome, thus implemented (episode 31) → **negative evaluation outcome results in need for option generation, positive outcome results in implementation**
- Episode started with progress from level 0 to 3, and 2 emergent processes (level 4 and 5) resulting in negative outcomes; first stage is option generation by observing terrain (level 4), the second stage evaluation (level 5); outcome is positive, thus action follows (episode 36) → **positive outcome results in implementation, although in this case the evaluation was based on a wrong assumption**
- First stage is level 2 and 3, triggers context change descriptor: response uncertainty; the result of level 3 automatically rules out an obvious option; at second stage access of response repertoire to retrieve another option (level 4)

(episode 43) → **level 3 rules out option, not further evaluate as it is only initial thoughts, he is not on scene yet**

- First stage is about speculating what caused tower collapse, concluding that this might happen in the second tower as well (level 1 within level 3); second stage is using this insight with all the previous cues to conclude what should be done (level 4), i.e. option generation (episode 47) – no context change → **people look at the chief to tell them what to do**
- First stage is level 2, triggers context change descriptor: response uncertainty; the result of level 3 at second stage automatically rules out an obvious option; (level 4) (episode 49) → **level 3 rules out option, not further evaluate as it is only initial thoughts, he is not on scene yet, meaning of cues for operational response required**

Multiple stage process at level 5

- Previously level 4 and 5 with drop back; First part of stage 1 is option generation brought about by observation activity (level 4), second part of stage 1, i.e. cue use, about evaluation of that option (level 5), outcome is unsatisfactory, thus no progress to implementing option, drop back to level 4; new option (level 4) needs not be created because he is doing it anyway (crawling away) but is evaluated in second stage with positive outcome, thus implemented (episode 31) → **evaluation triggered to see if there is danger originating from that option; second option: evaluation triggered as comparison with first option to see which one is the preferable one**
- Episode started with progress from level 0 to 3, and 2 emergent processes (level 4 and 5) resulting in negative outcomes; first stage is option generation by observing terrain (level 4), the second stage evaluation (level 5); outcome is positive, thus action follows (episode 36) → **evaluation triggered to see if it fits with his criteria; positive outcome results in implementation, although in this case the evaluation was based on a wrong assumption**

Other mechanisms

Why move from 2-3?

You need to understand what is going on before you can establish what it means

- Episode 7: explosion happens above him, personal involvement in potentially risky situation, personal safety, close distance; level 2 = what is going on, level 3 = meaning
- Episode 9: environment changes quickly, personal involvement and safety, operational consequences in terms of evacuation; level 2 = what is going on, level 3 = meaning
- Episode 11: safety, risk, operational consequences in terms of command post safety; level 2 = what is going on, level 3 = meaning
- Episode 16: consequences of factual knowledge in terms of reaching a goal needs to be understood; level 2 = what is currently known, level 3 = meaning for reaching goal

- Episode 23: consequences of current location for command post location effectiveness, i.e. operational effectiveness; level 2 = current situation; level 3 = meaning for operational effectiveness
- Episode 37: personal involvement in potentially risky situation, personal safety; level 2 = what is going on, level 3 = meaning for risks and personal health and safety
- Episode 44: personal involvement in potentially risky situation, personal safety; level 2 = what is going on, level 3 = meaning for risks and personal health and safety
- Episode 49: situation observed in beginning stage of incident, meaning/consequences for operations needs to be understood level 2 = current situation; level 3 = meaning for operational effectiveness
- Episode 1: personal involvement in potentially risky situation, personal and crew safety; level 2 = what is going on, level 3 = meaning for risks and personal / crew health and safety
- Episode 20: personal involvement in potentially risky situation, personal safety; level 2 = what is going on, level 3 = meaning for risks and personal health and safety

Why move from 4-5?

- Episode 31:outcome not aligned with search criteria or goal; triggers need to find another for personal involvement and safety reasons
- Episode 36: need to establish value of option in reaching goal or fitting criteria; personal safety involved

Why move from 3-4?

- Episode 47: need to understand what consequences of situation mean for operations, consequence was potential danger, need to understand what this means for next actions of whole crew; personal, crew and civilian safety

Appendix D12 - Levels of understanding and underlying mechanisms in the multiple input generation process

Episodes by level

Multiple input process level 2

- Multiple inputs are observed facts (direct understanding at level 2), the second part of the process is about moving to level 3 (episode 27) – context change descriptor: effect uncertainty
- Multiple inputs are observed facts (direct understanding at level 2), the second part of the process is about moving to level 3 (episode 39) – context change descriptor: effect uncertainty
- Multiple inputs are recorded over time on command board (level 2) (episode 53) to build and maintain level 2 (might be seen as emergent process) – no context change

Multiple input process level 3

- Multiple inputs are observed facts (direct understanding at level 2), the second part of the process is about moving to level 3 (episode 27) – context change descriptor: effect uncertainty → **meaning for the facts in terms of consequences created**
- Multiple inputs are observed facts (direct understanding at level 2), the second part of the process is about moving to level 3 (episode 39) – context change descriptor: effect uncertainty → **meaning for the facts in terms of consequences created**

Other mechanisms

- Episode 27: level 2-3; operational consequences of a situation need to be understood, crew safety, command post safety
- Episode 39: level 2-3; operational consequences of a situation need to be understood, crew safety, command post safety
- Episode 53: level 2, 2+; need to understand the bigger picture made up from fragments, need to understand the developing incident response
- Episode 30: level 2, 2+; need to understand the bigger picture made up from fragments, need to understand the developing incident response
- Episode 40: level 2, 2+; need to understand the bigger picture made up from fragments, need to understand the incident

Appendix E1 – Interview guideline used for expert review at the Fire Service College

Introduction to the research
The research topic: Building and improving understanding of situations during incident response
Traditionally:
- we know about decision making and situation awareness
- we know that commanders need to understand the overall incident, risks, resources etc.
- we don't know how this process looks like in detail, what exactly does a person try to understand during a sudden situation development, how does understanding evolve?

What I have done:
- Analyse interviews with senior officers of the FDNY to recreate the process they use to create understanding
- Typical operational tasks, life threatening situations, sudden situation developments

What I have found:
- The overall process happens in stages
- Stages are tied to gaining understanding
    - 7 levels
- Factors that trigger stages
    - 4 cognitive factors, Need to understand, 3 situational factors

Purpose of today:
- See if the levels of understanding and mechanisms that trigger stages resonate with your experience
- Your personal and practitioner view on my findings, examples from your own experience
- What the findings might mean in the wider context of incident command (training)

<u>**Expert review – Question guideline**</u>

Questions
What are your initial thoughts on the work?
Have you got any examples from your own experience or from what you have seen in training that reflect what I have found?
Where is this different to what you teach on incident command?
What are your thoughts about the list of factors?
- Missing elements? Elements to be corrected or deleted?

What do the findings mean to you in the wider context of incident command? Are there any implications for incident command?
How could the findings inform incident response training?

Appendix E2 – Diagrams on findings used in expert review at the Fire Service College

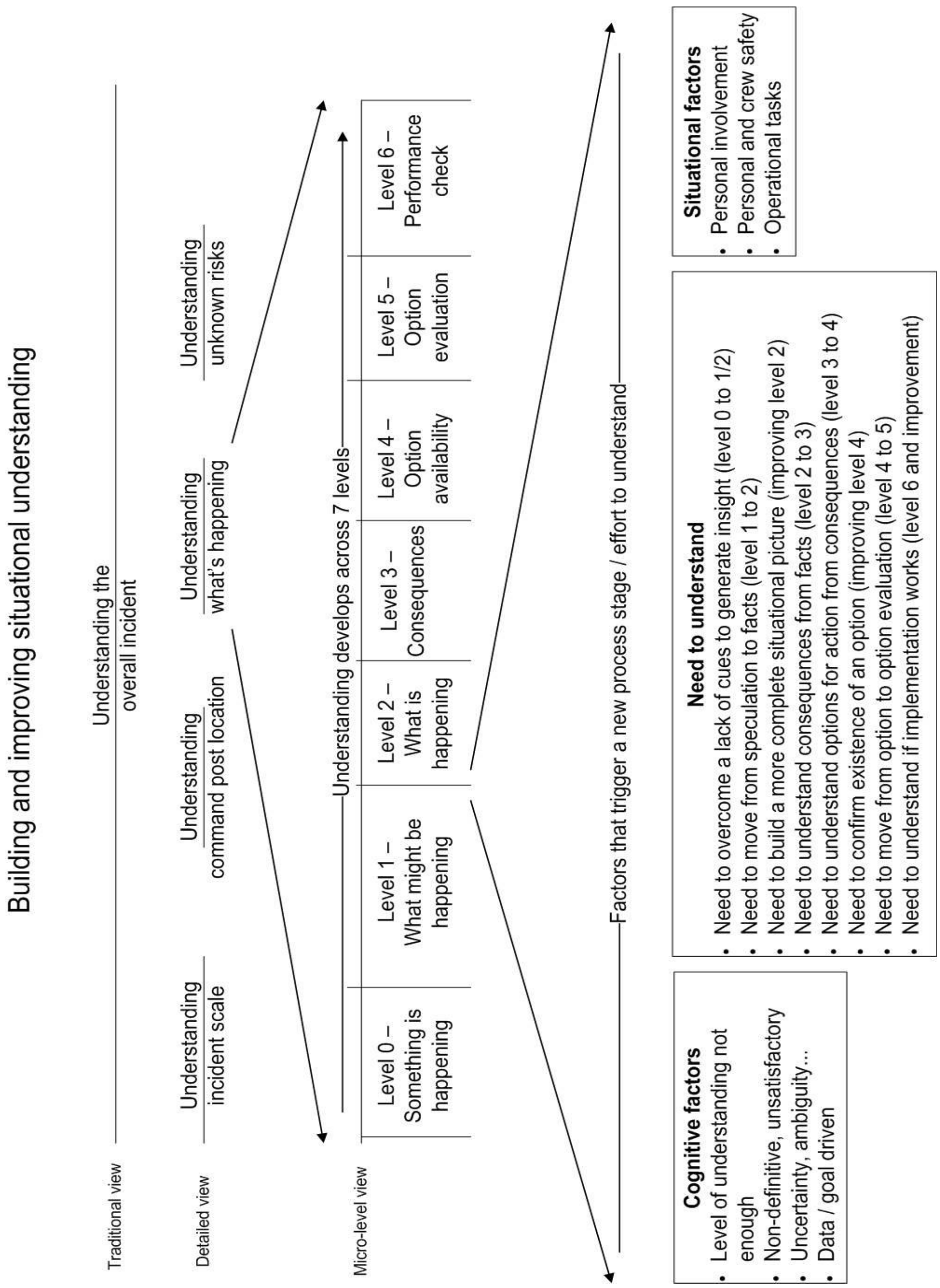
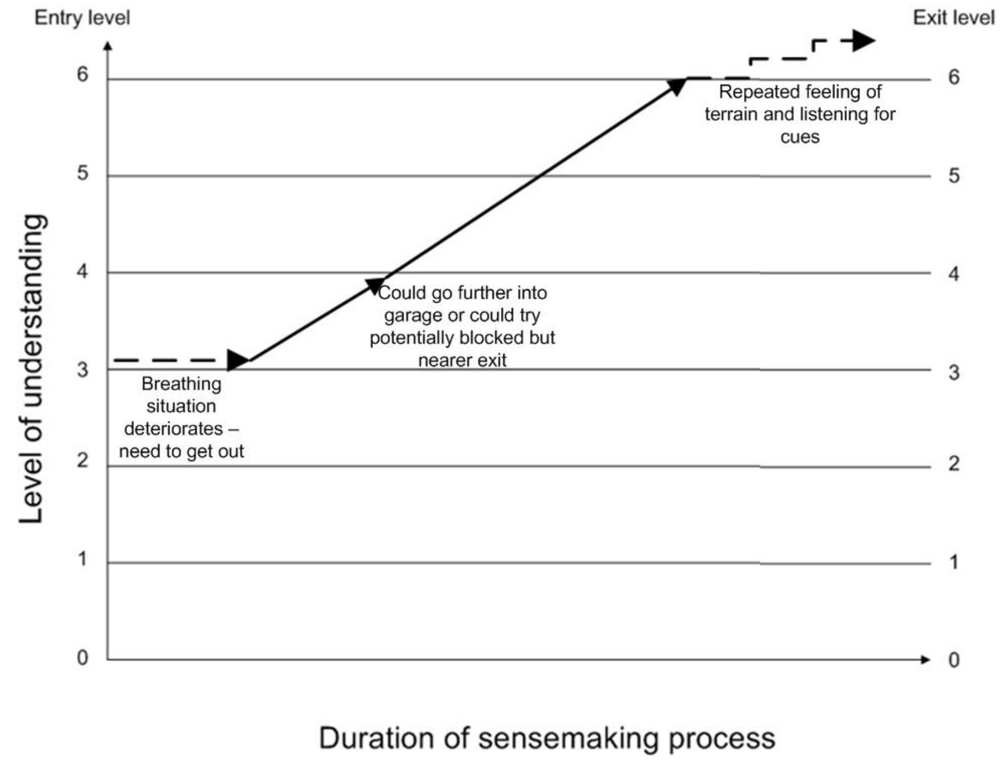


Figure E1 – Finding summary and illustration in incident command context for expert review



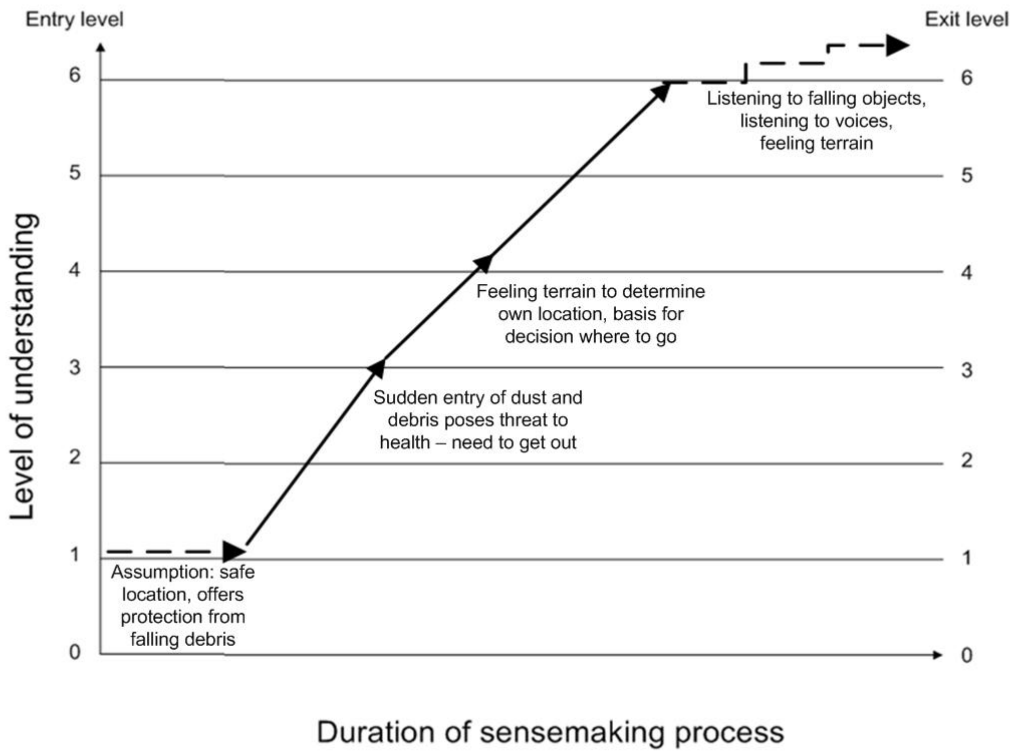
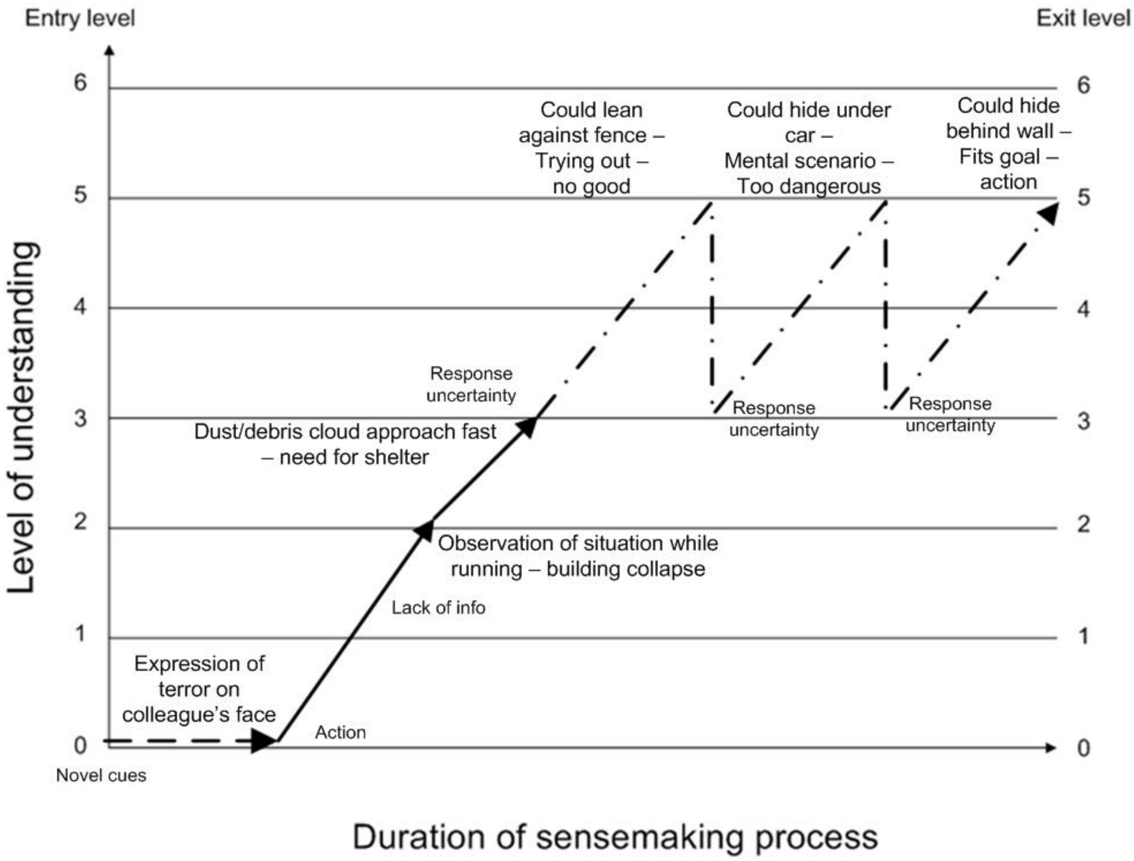


Figure E2 – Evolving understanding – Example 1 for expert review



Stage triggers

- **Level of understanding not enough**
- **Non-definitive, unsatisfactory understanding**
- **Novel cues, lack of info, response uncertainty**
- **Data / goal driven**
- **Need to overcome a lack of cues to generate insight (level 0 to 1/2)**
- Need to move from speculation to facts (level 1 to 2)
- Need to build a more complete situational picture (improving level 2)
- **Need to understand consequences from facts (level 2 to 3)**
- **Need to understand options for action from consequences (level 3 to 4)**
- Need to confirm existence of an option (improving level 4)
- **Need to move from option to option evaluation (level 4 to 5)**
- Need to understand if implementation works (level 6 and improvement)
- **Personal involvement**
- **Personal** and crew **safety**
- Operational tasks

Figure E3 – Evolving understanding and link to underlying mechanisms – Example 2 for expert review